US009106362B2

(12) **United States Patent**
Matsumoto et al.

(10) **Patent No.:** **US 9,106,362 B2**
(45) **Date of Patent:** **Aug. 11, 2015**

(54) **OPTICAL UNIT FOR WAVELENGTH SELECTING SWITCH AND WAVELENGTH SELECTING SWITCH**

(71) Applicant: **JDS Uniphase Corporation**, Milpitas, CA (US)

(72) Inventors: **Koji Matsumoto**, Tokyo (JP); **Toshiro Okamura**, Tokyo (JP); **Satoshi Watanabe**, Tokyo (JP); **Takeshi Yamazaki**, Tokyo (JP)

(73) Assignee: **JDS Uniphase Corporation**, Milpitas, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/015,377**

(22) Filed: **Aug. 30, 2013**

(65) **Prior Publication Data**

US 2014/0037288 A1 Feb. 6, 2014

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2012/001323, filed on Feb. 27, 2012.

(30) **Foreign Application Priority Data**

Mar. 2, 2011 (JP) 2011-045713
Mar. 24, 2011 (JP) 2011-066160
Mar. 24, 2011 (JP) 2011-066541

(51) **Int. Cl.**
G02B 6/35 (2006.01)
H04J 14/02 (2006.01)

(52) **U.S. Cl.**
CPC ***H04J 14/02*** (2013.01); ***G02B 6/3504*** (2013.01)

(58) **Field of Classification Search**
CPC G02B 6/3518; G02B 6/356; G02B 6/3548
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,630,599	B2	12/2009	McLaughlin et al.	
7,720,329	B2 *	5/2010	Presley et al.	385/18
7,769,255	B2 *	8/2010	Nagy et al.	385/18
7,808,705	B2 *	10/2010	Kobayashi et al.	359/618
8,036,502	B2 *	10/2011	Duricic et al.	385/16
2009/0154876	A1	6/2009	McLaughlin et al.	

FOREIGN PATENT DOCUMENTS

JP	2000-181377 A	6/2000
JP	2001-141971 A	5/2001

(Continued)

OTHER PUBLICATIONS

International Search Report dated May 29, 2012 issued in PCT/JP2012/001323.

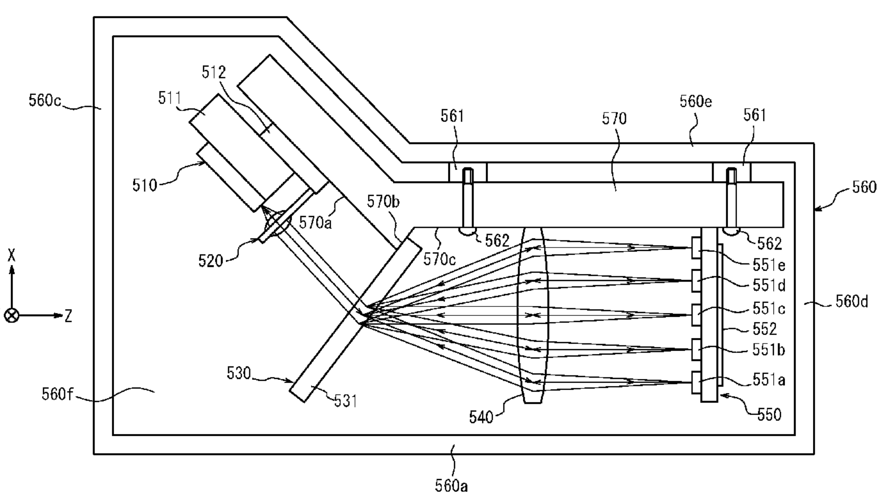
Primary Examiner — Omar R Rojas

(74) *Attorney, Agent, or Firm* — Matthew A. Pequignot; Pequignot + Myers LLC

(57) **ABSTRACT**

An optical unit for a wavelength-selecting switch according to the present invention comprises: an input port; a dispersion section that produces wavelength dispersion of input light that is input from the input port; a light-collecting element that collects the light dispersed by the dispersion section; an output port; an optical path correction section that shifts the light that is dispersed by the dispersion section; an adjustment section that changes the amount of shift produced by the optical path correction section; and a casing that hermetically seals the input port, dispersion section, light-collecting element, output port, and optical path correction section. The casing has an optically transparent section in a location onto which the light that is collected by the light-collecting element is directed. The adjustment section is arranged outside the casing. The optical path correction section can be controlled from outside the casing by the adjustment section.

10 Claims, 36 Drawing Sheets



(56) **References Cited**

FOREIGN PATENT DOCUMENTS

JP	2007-101670	A	4/2007
JP	2008-164630	A	7/2008
JP	2008-310244	A	12/2008
JP	2009-134294	A	6/2009
JP	2009-145887	A	7/2009
WO	WO 2010/001734	A1	1/2010

* cited by examiner

FIG. 1A

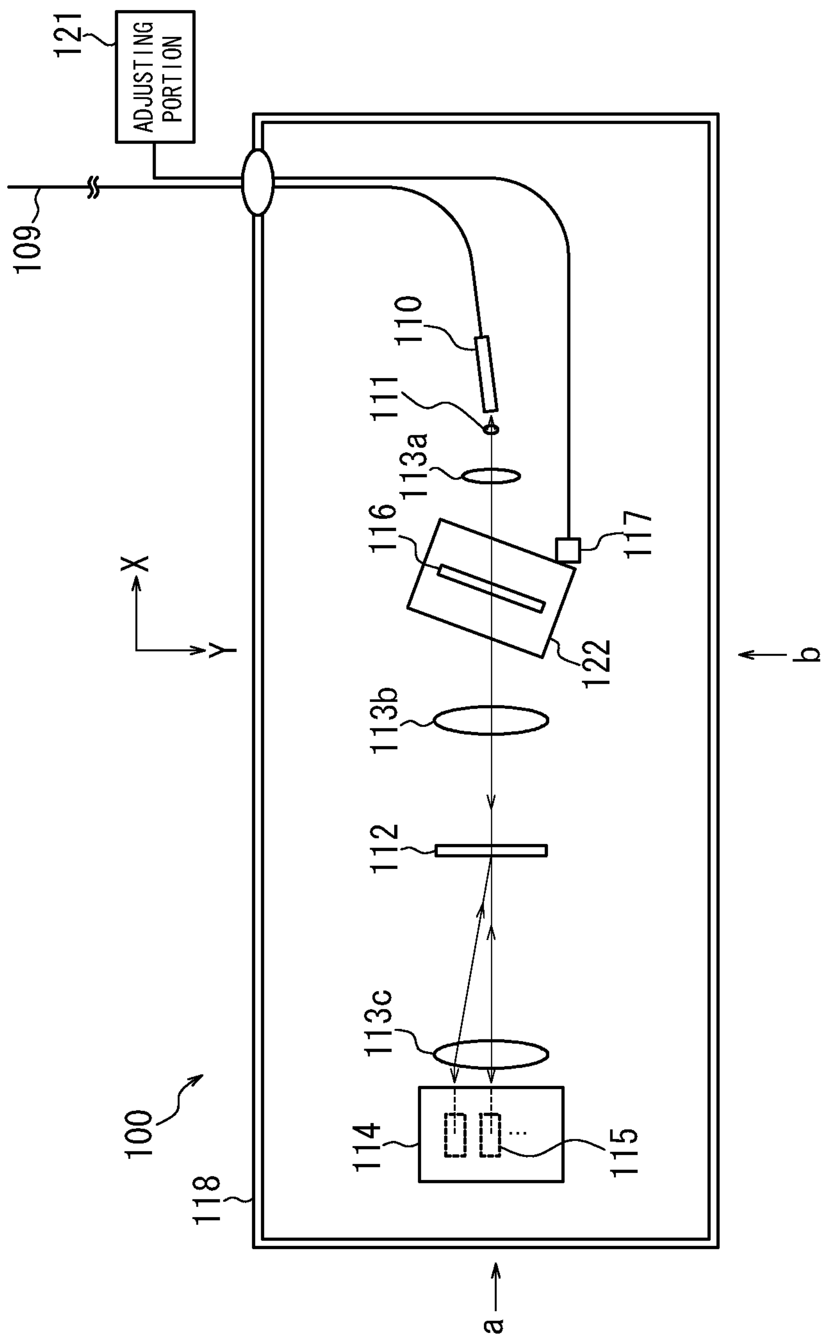
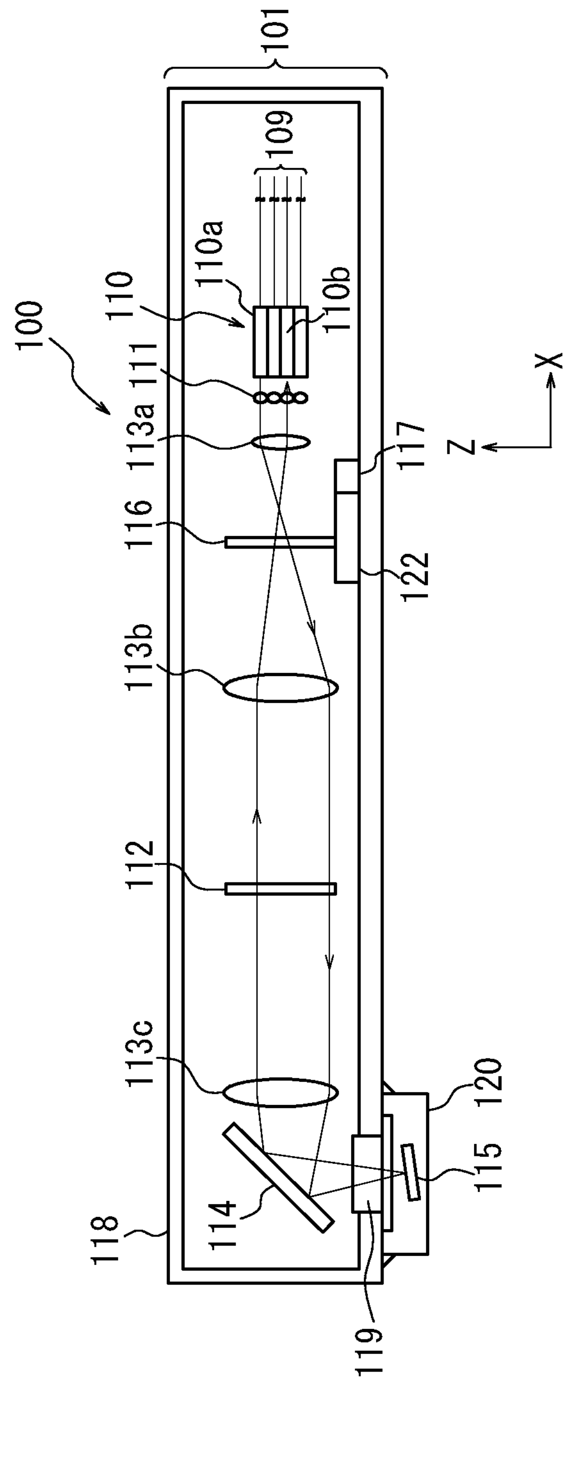

121
ADJUSTING PORTION
109
110
111
113a
116
117
X
Y
122
113b
112
113c
100
114
115
118
a
b

FIG. 1B



101
109
110a
110
110b
100
111
113a
116
113b
112
113c
114
118
119
115
120
122
117
X
Z

FIG. 2A

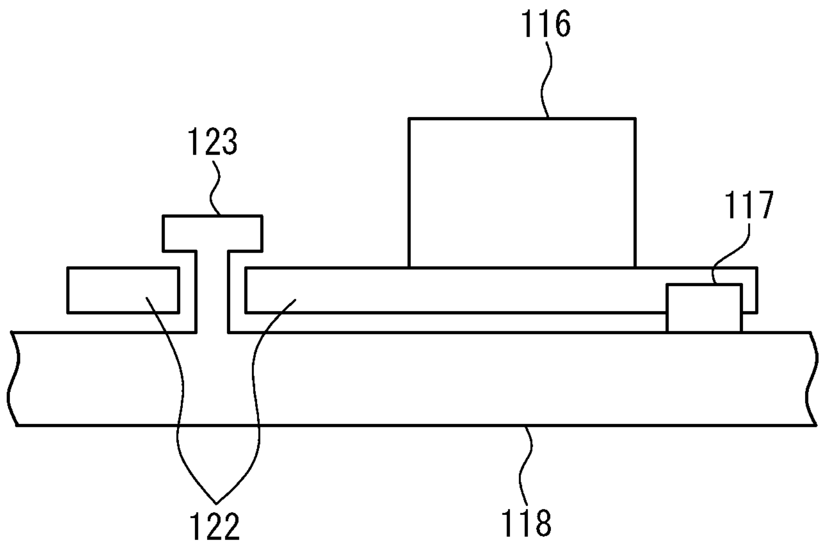


FIG. 2B

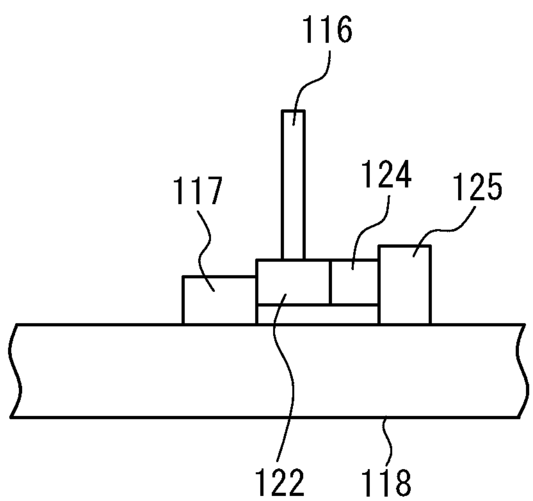


FIG. 2C

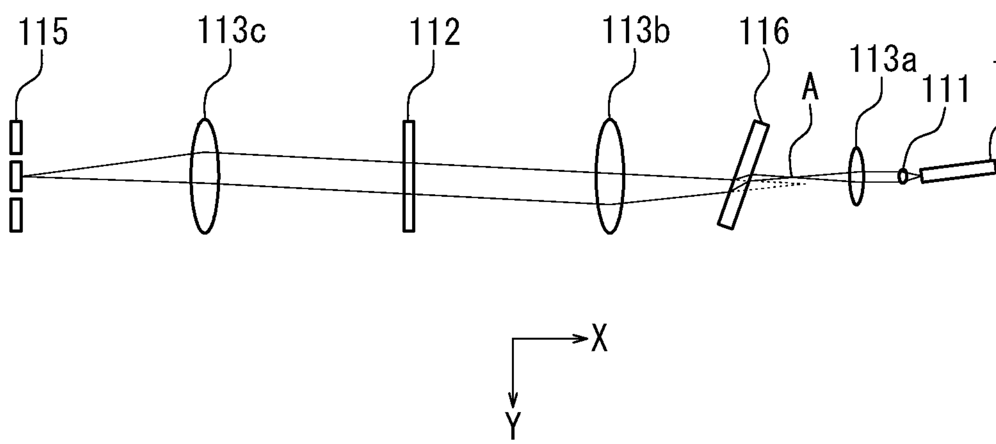


FIG. 3A

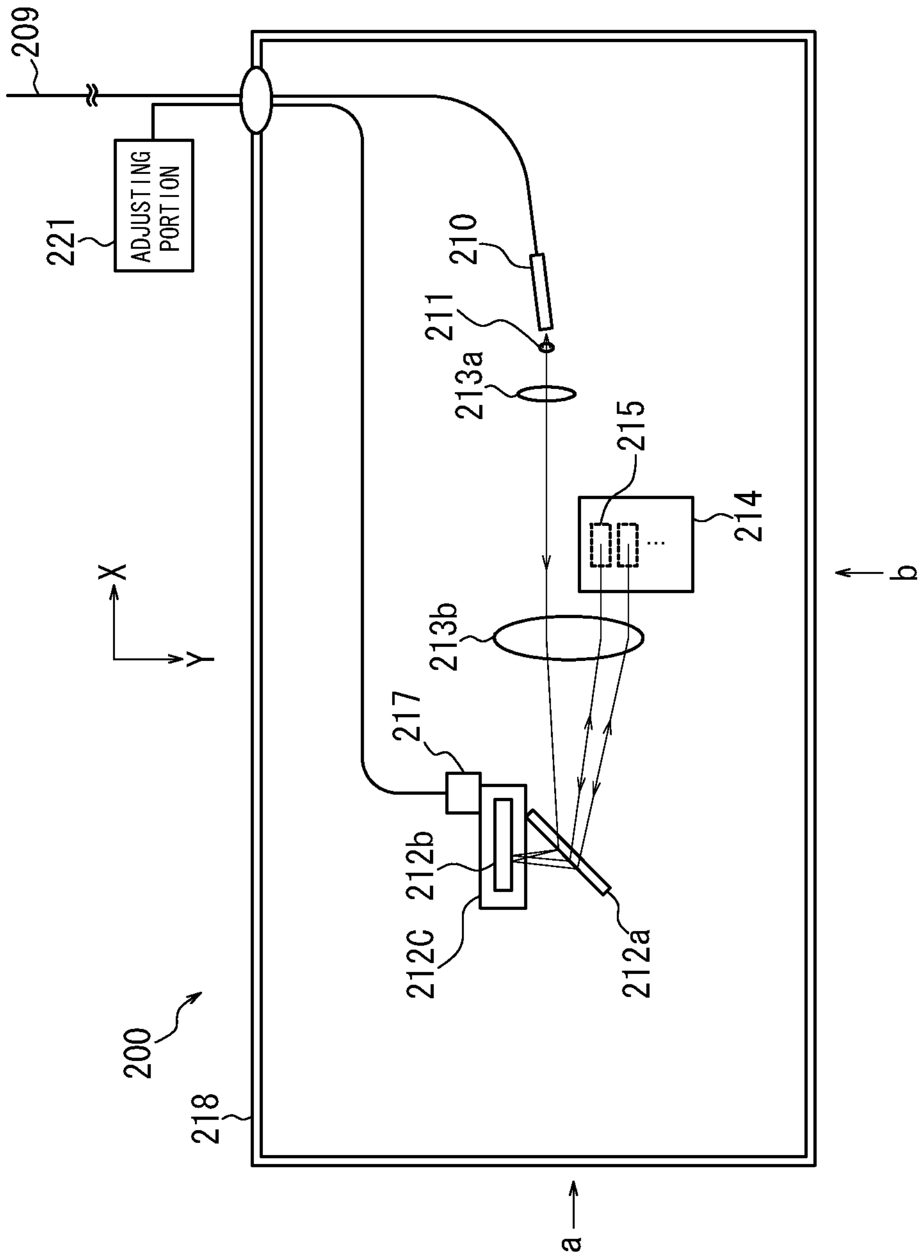

209
221
ADJUSTING PORTION
210
211
213a
215
214
X
Y
213b
217
212b
212C
212a
200
218
a
b

FIG. 3B

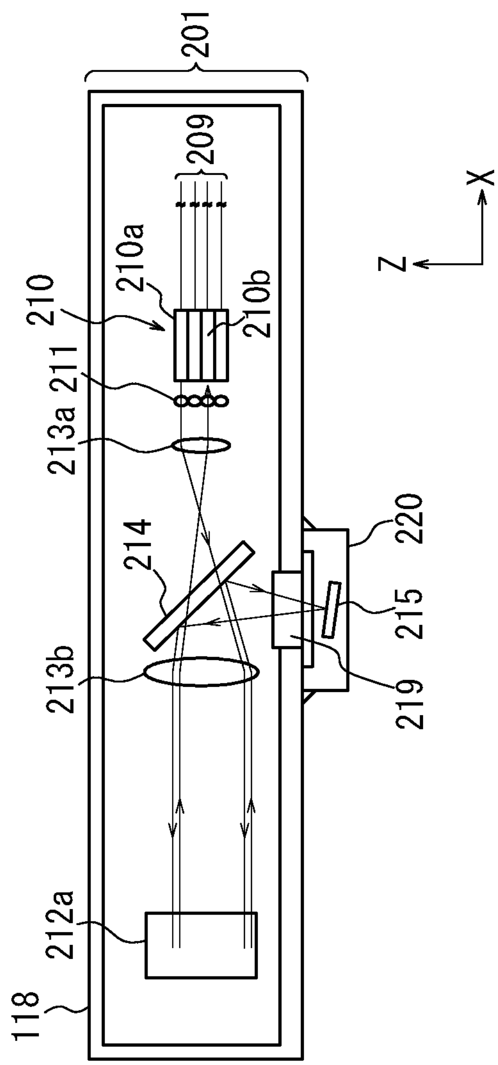

201
209
200
210
210a
210b
211
213a
214
213b
212a
118
220
215
219
X
Z

FIG. 3C

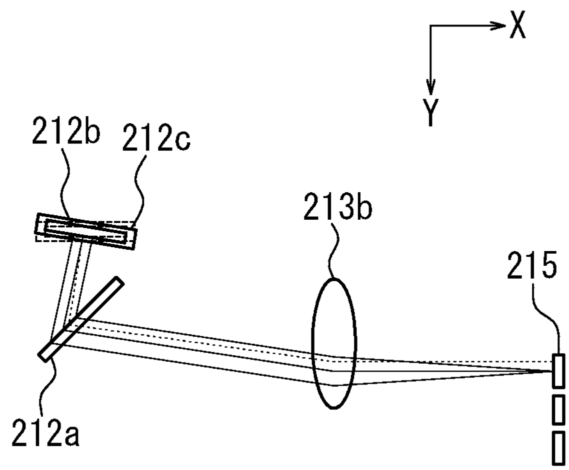


FIG. 4A

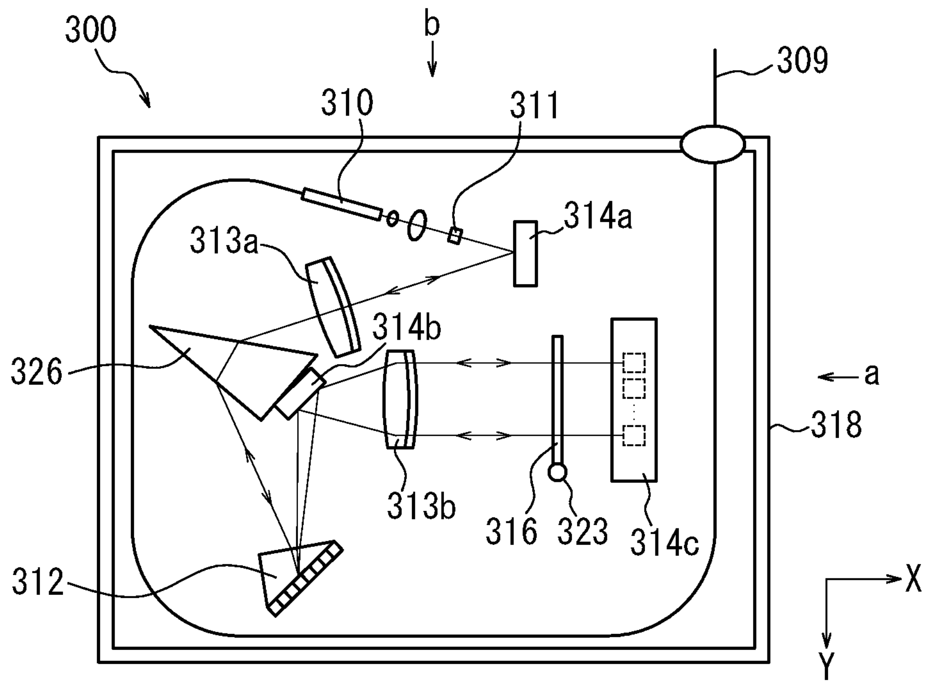

300
b
310
311
309
314a
313a
314b
326
a
318
313b
316
323
314c
312
X
Y

FIG. 4B

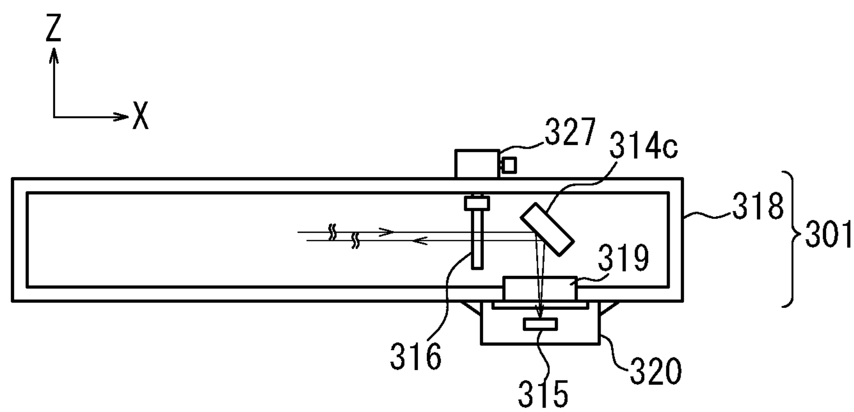

Z
X
327
314c
318
301
319
316
320
315

FIG. 5A

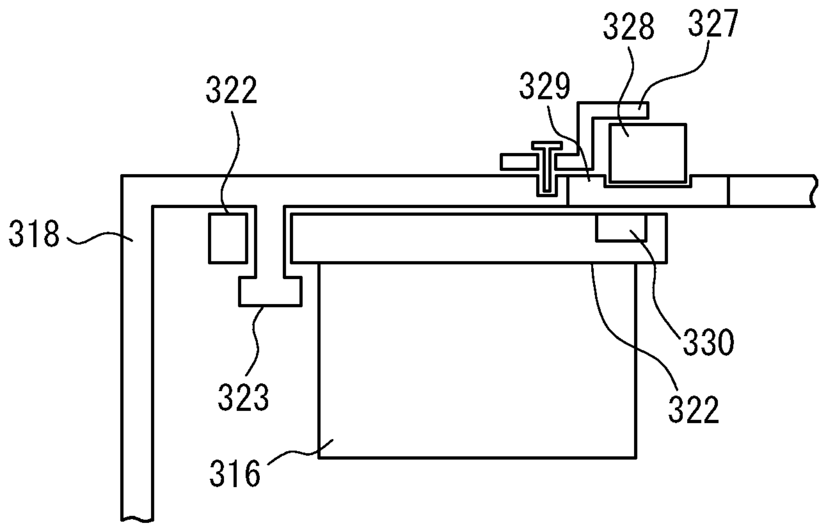

328
327
329
322
318
330
323
322
316

FIG. 5B

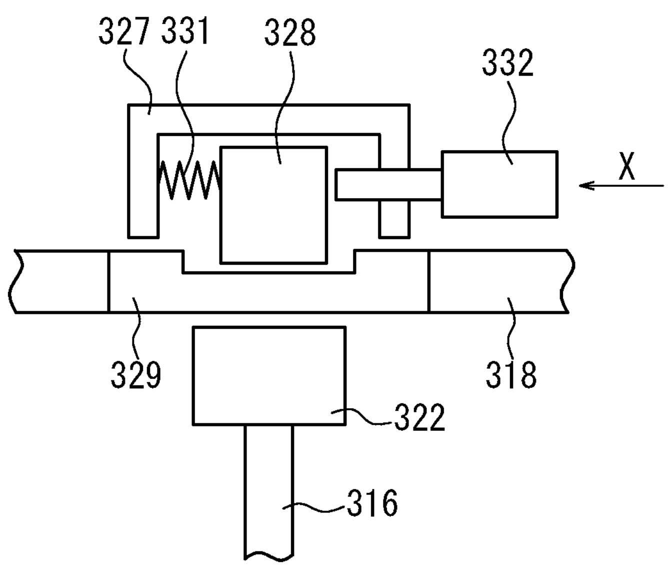

327
331
328
332
X
329
318
322
316

FIG. 5C

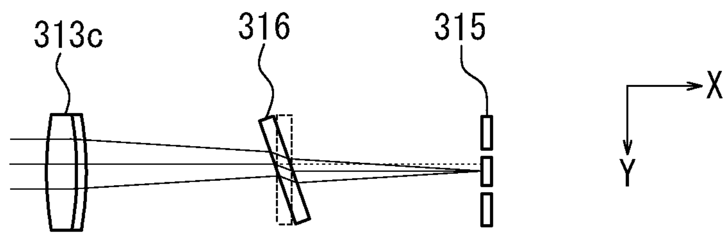


FIG. 6

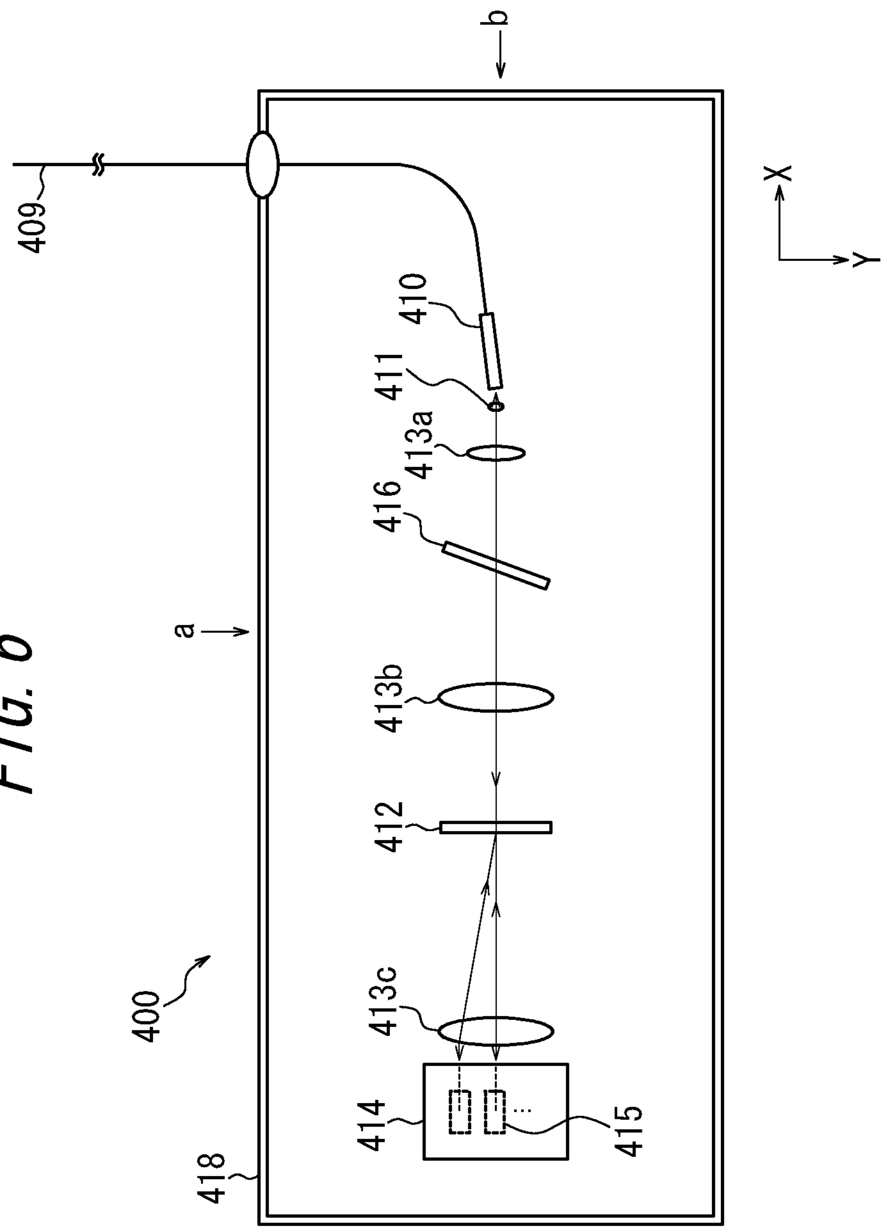


FIG. 7A

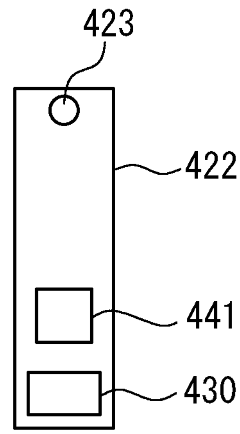


FIG. 7B

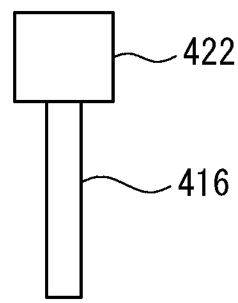


FIG. 7C

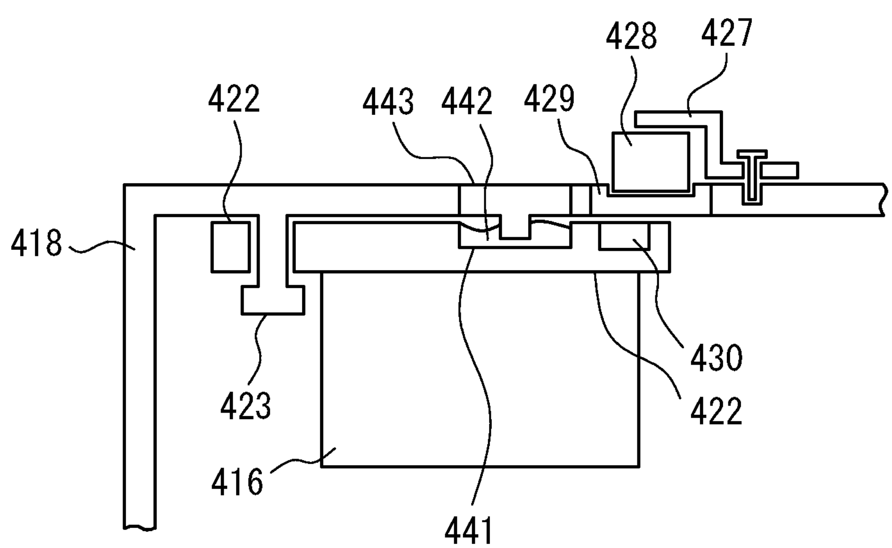


FIG. 8A

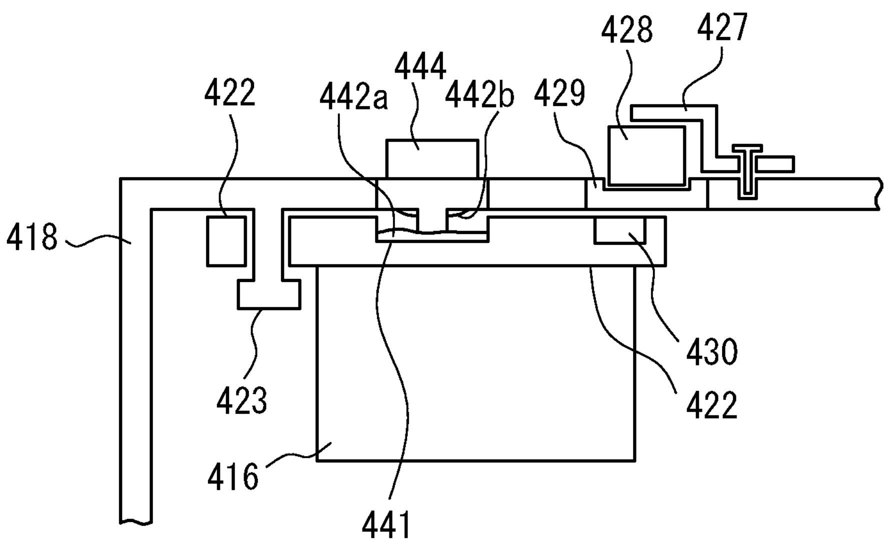


FIG. 8B

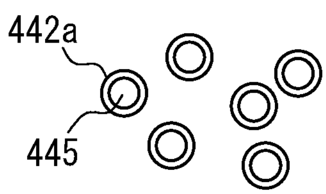


FIG. 9

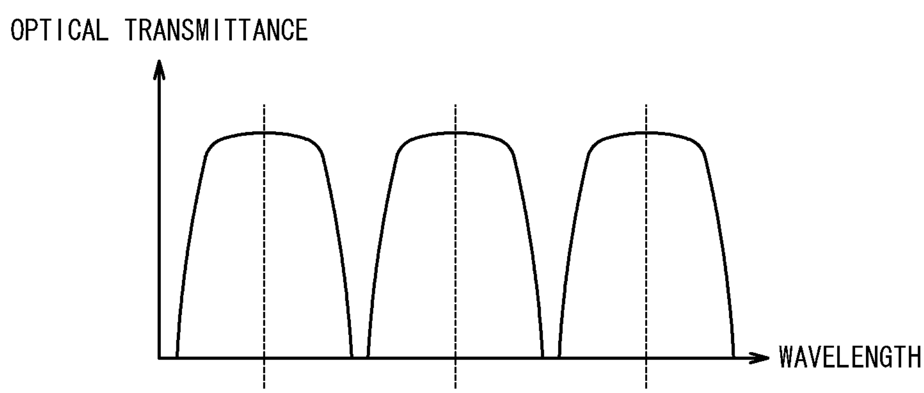


FIG. 10A

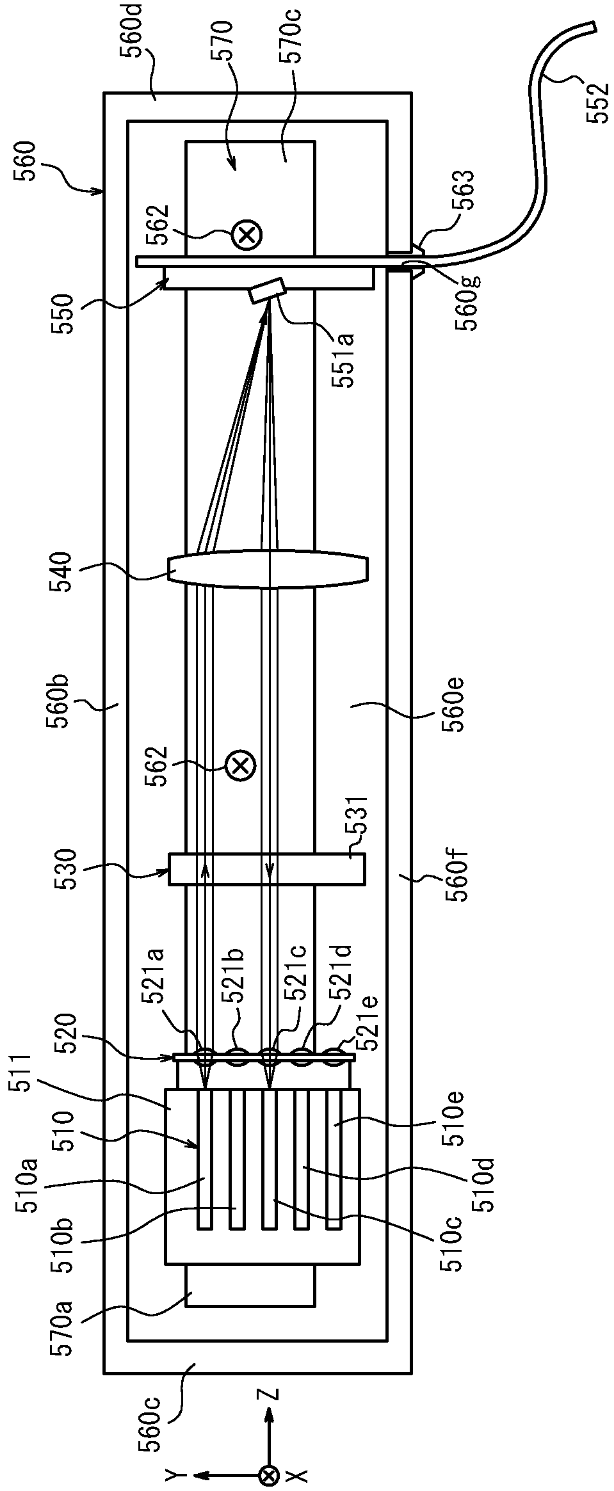

560d
570
570c
552
560
562
563
550
560g
551a
540
560b
560e
562
530
531
560f
521a
521b
521c
521d
521e
520
511
510
510a
510b
510c
510d
510e
570a
560c
Z
Y
X

FIG. 10B

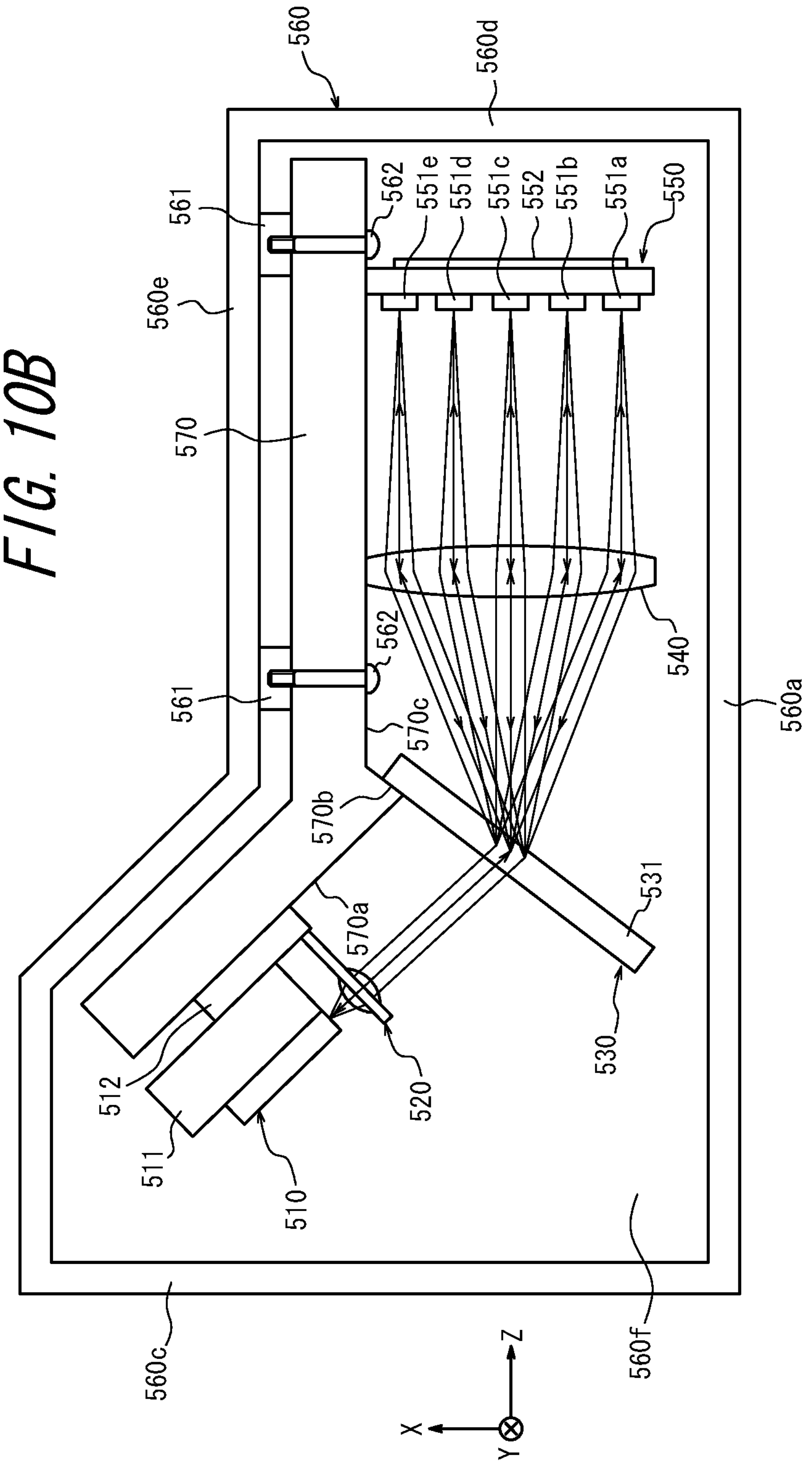

560
560d
561
562
551e
551d
551c
552
551b
551a
550
560e
570
540
562
561
570c
560a
570b
531
570a
512
520
530
511
510
560c
560f
Z
X
Y

FIG. 11A

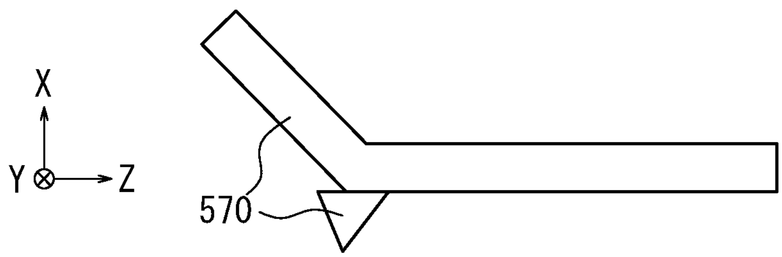


FIG. 11B

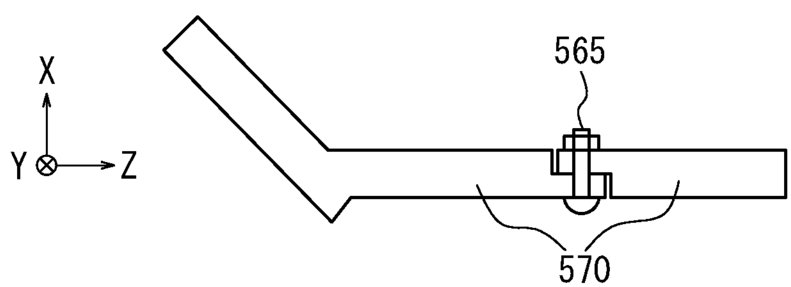
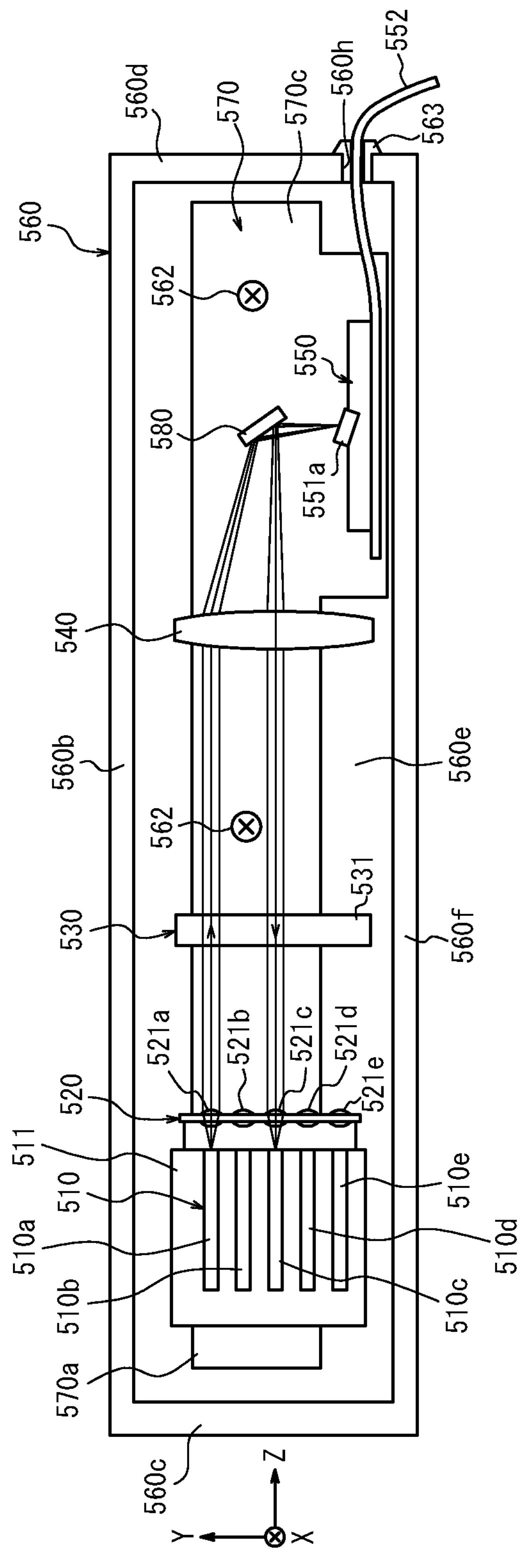


FIG. 12A



552
560h
563
560d
570
570c
560
562
550
580
551a
540
560b
560e
562
531
530
560f
521a
521b
521c
521d
521e
520
511
510
510e
510a
510d
510b
510c
570a
560c
Z
Y
X

FIG. 12B

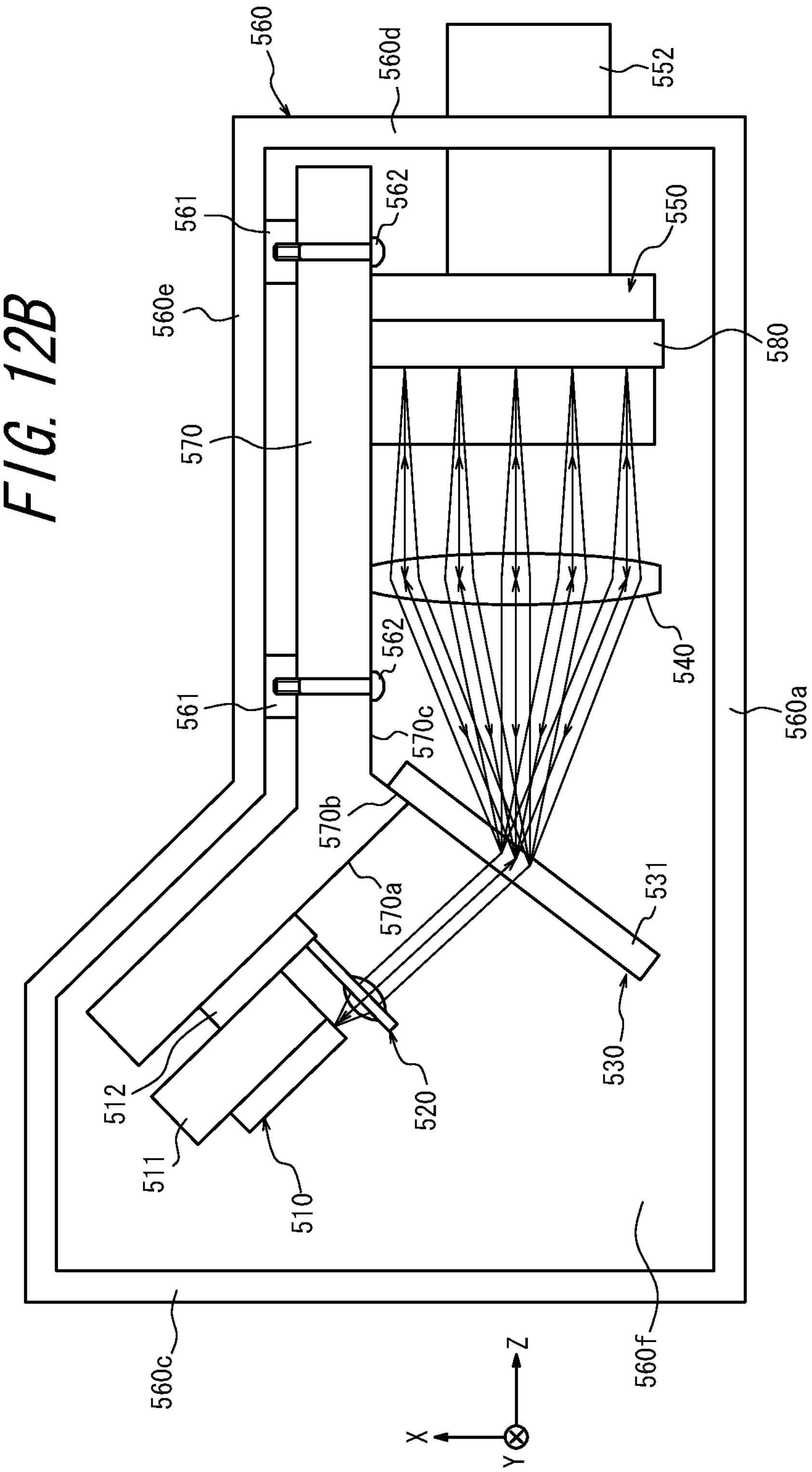

560
560d
552
561
562
550
560e
580
570
540
562
561
570c
560a
570b
570a
531
530
520
512
511
510
560c
560f
Z
X
Y

FIG. 13A

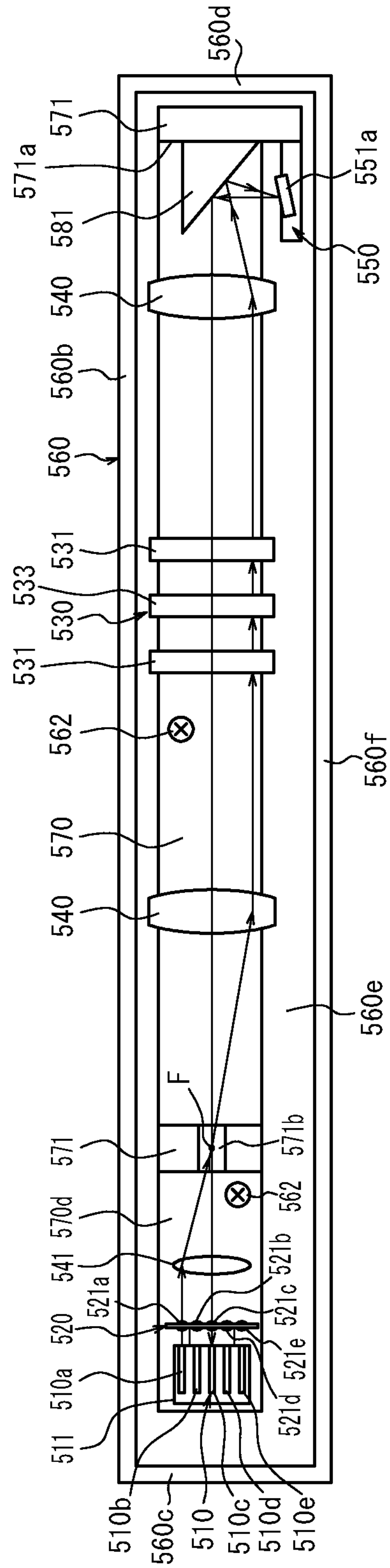

560d
571
571a
581
551a
550
540
560b
560
531
533
530
531
562
570
540
560f
560e
F
571
571b
570d
562
541
521a
521b
521c
520
521e
510a
521d
511
510b
560c
510
510c
510d
510e

FIG. 13B

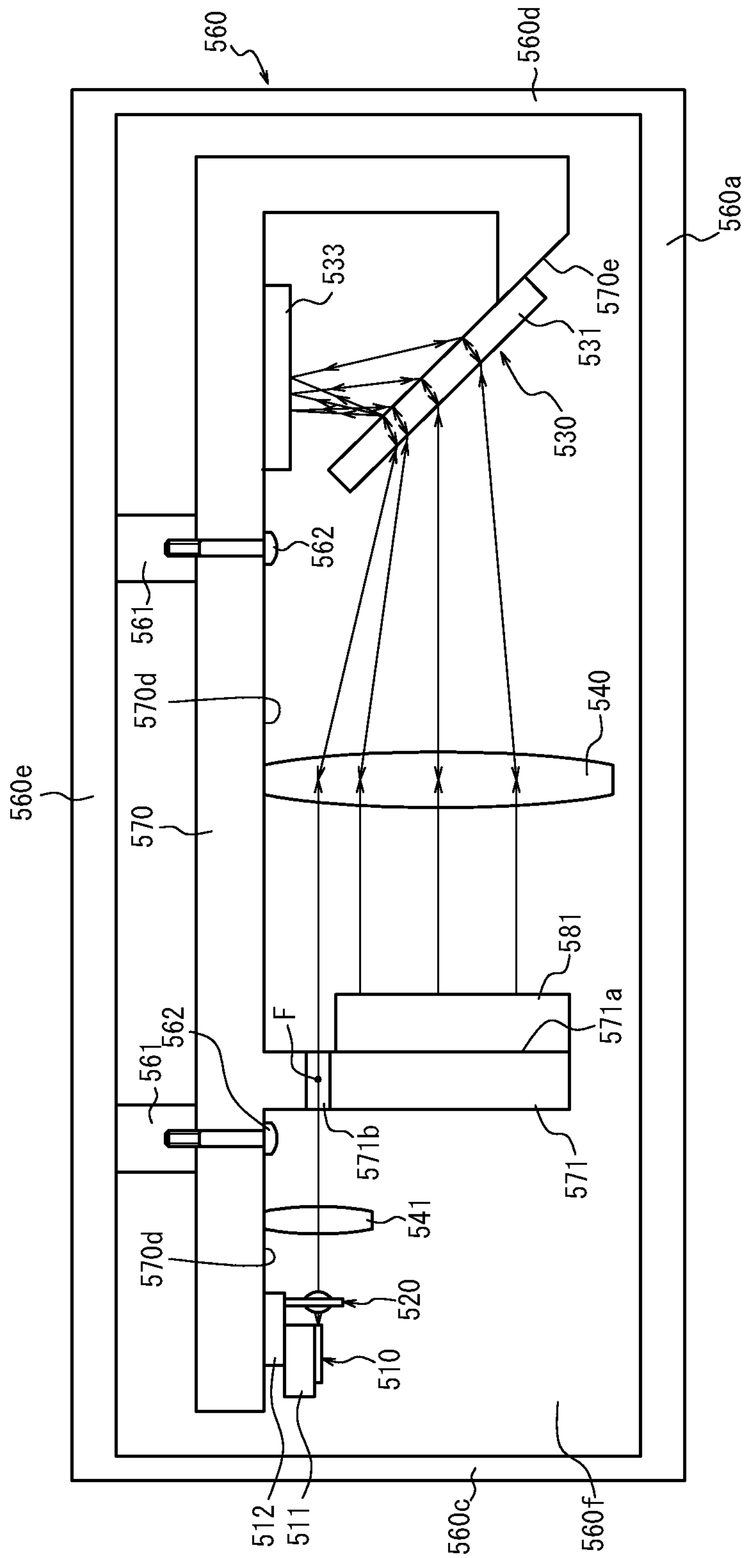

560
560d
560a
533
570e
531
530
562
561
570d
540
560e
570
581
571a
F
562
561
571b
571
541
570d
520
510
512
511
560c
560f

FIG. 14

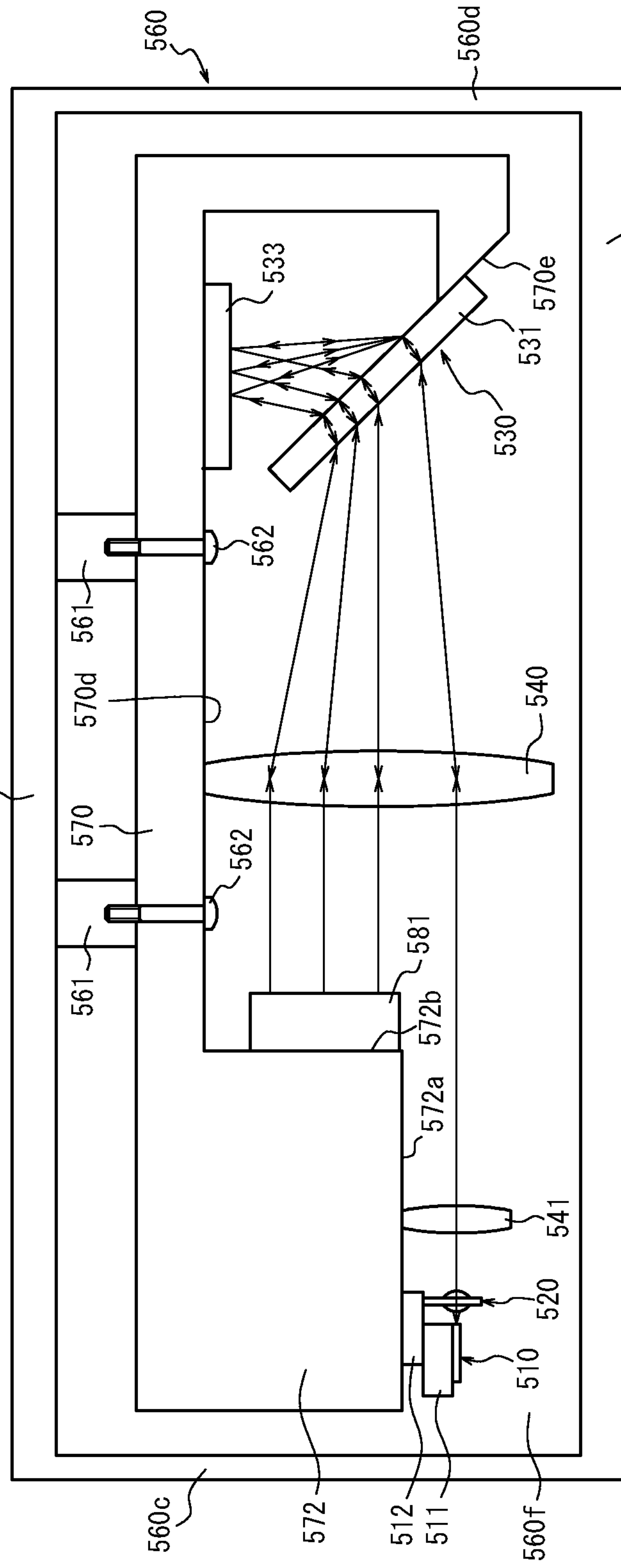
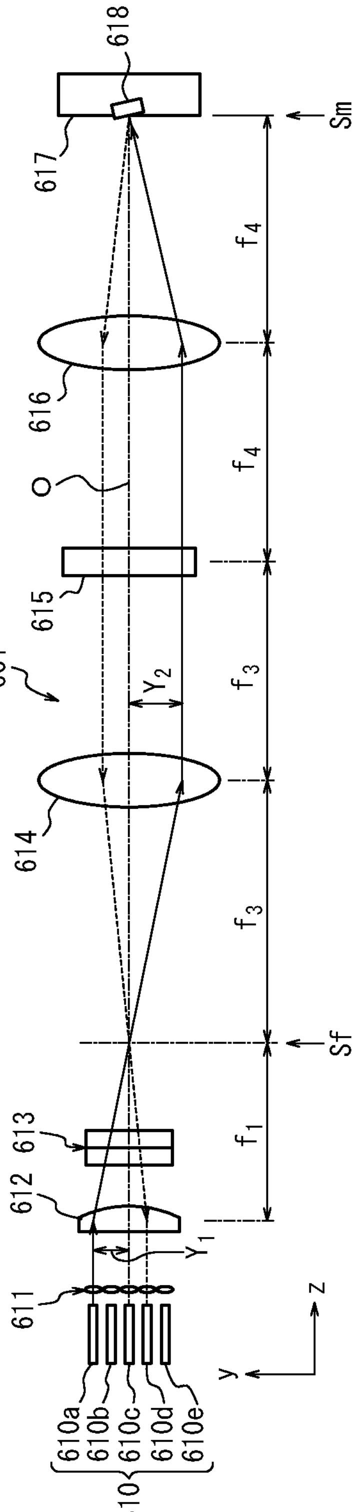

560
560d
560a
570e
533
531
530
562
561
570d
540
560e
570
562
581
572b
561
572a
541
520
510
560c
572
512
511
560f

FIG. 15A


618
617
Sm
f4
616
f4
O
615
601
Y2
f3
614
f3
Sf
f1
613
612
Y1
611
z
y
610a
610b
610c
610d
610e
610

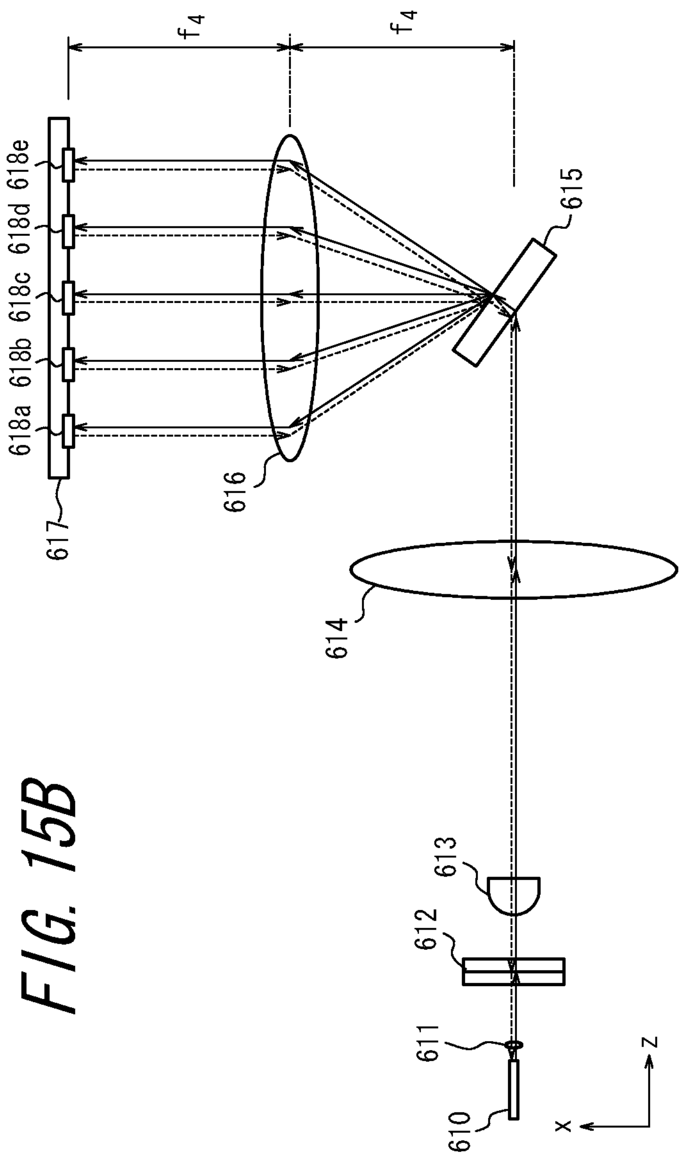

f4
f4
618a
618b
618c
618d
618e
615
616
617
614
613
612
611
610
x
z

FIG. 15B

FIG. 16

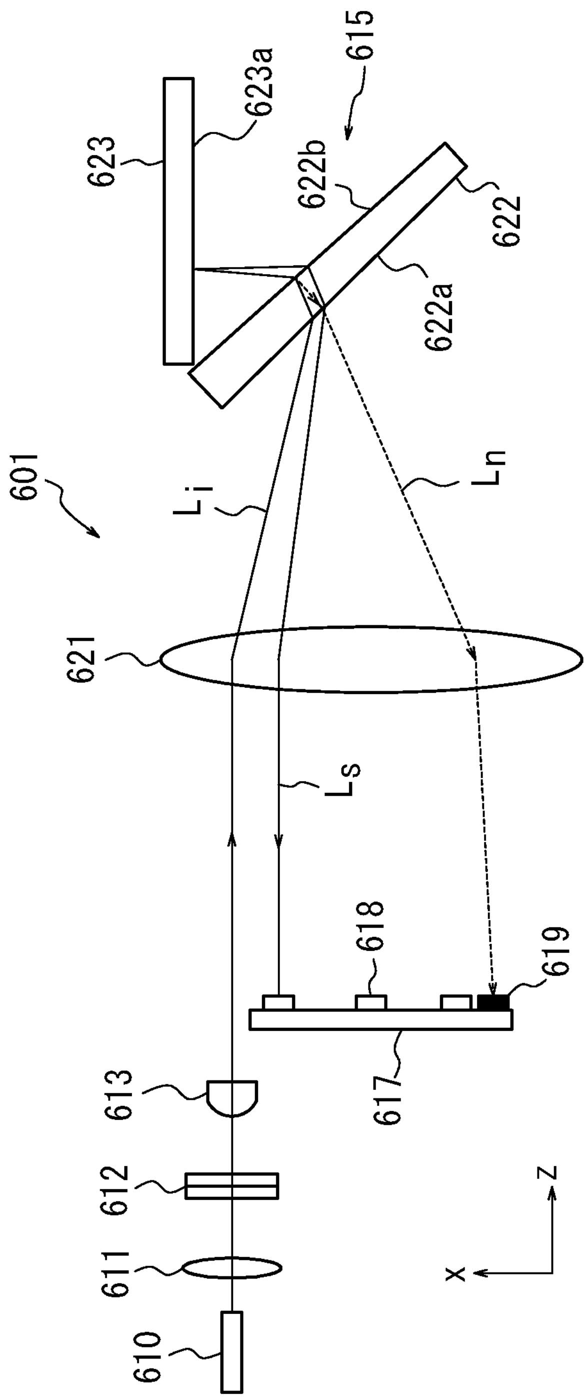

601
615
623
623a
622
622a
622b
L_i
L_n
L_s
621
618
619
617
613
612
611
610
x
z

FIG. 17

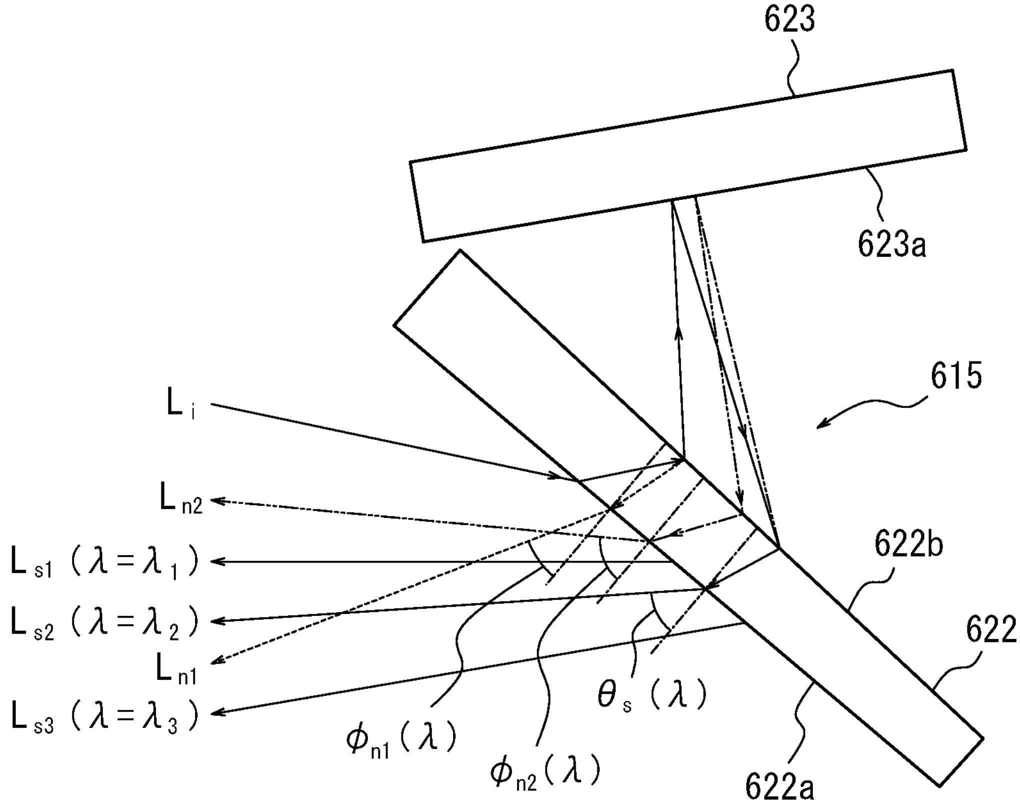
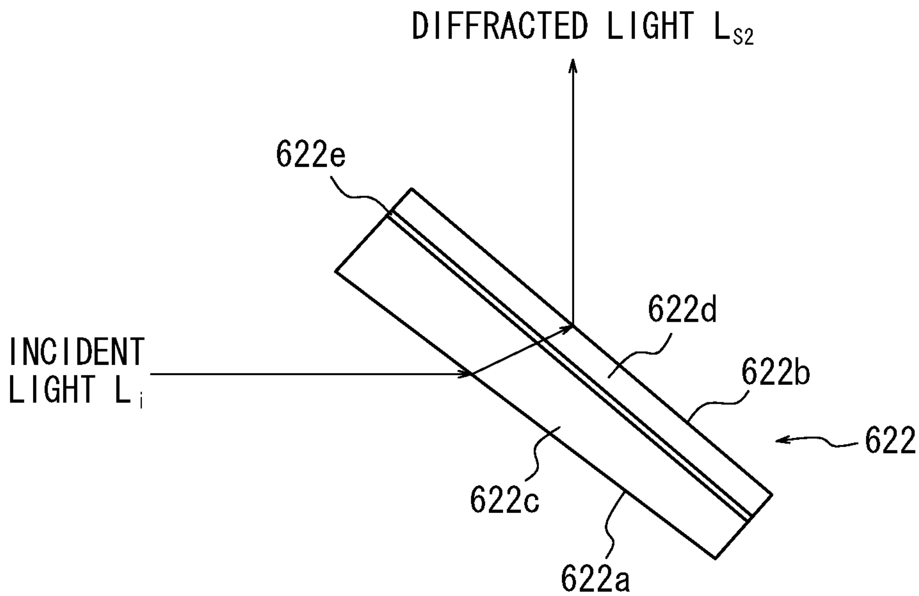

623
623a
615
622b
622
622a
L_i
L_{n2}
L_{s1} ($\lambda=\lambda_1$)
L_{s2} ($\lambda=\lambda_2$)
L_{n1}
L_{s3} ($\lambda=\lambda_3$)
$\phi_{n1}(\lambda)$
$\phi_{n2}(\lambda)$
$\theta_s(\lambda)$

FIG. 18



DIFFRACTED LIGHT L_{S2}
622e
622d
INCIDENT LIGHT L_i
622b
622
622c
622a

FIG. 19A FIG. 19B

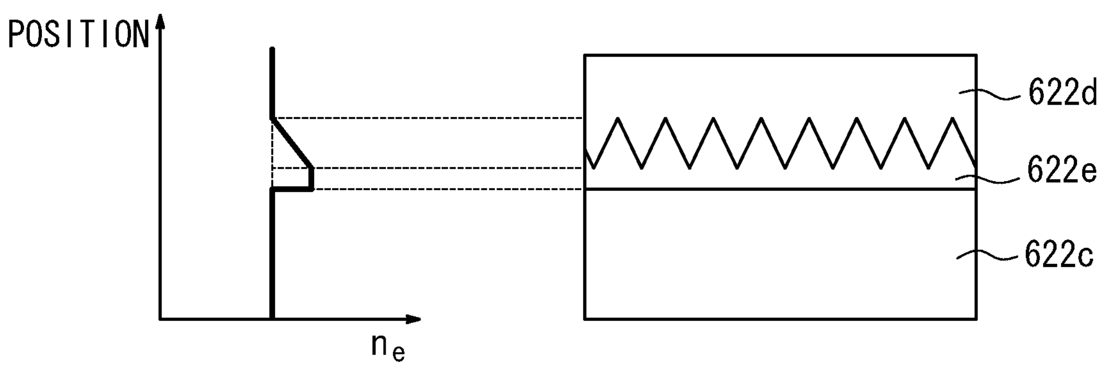
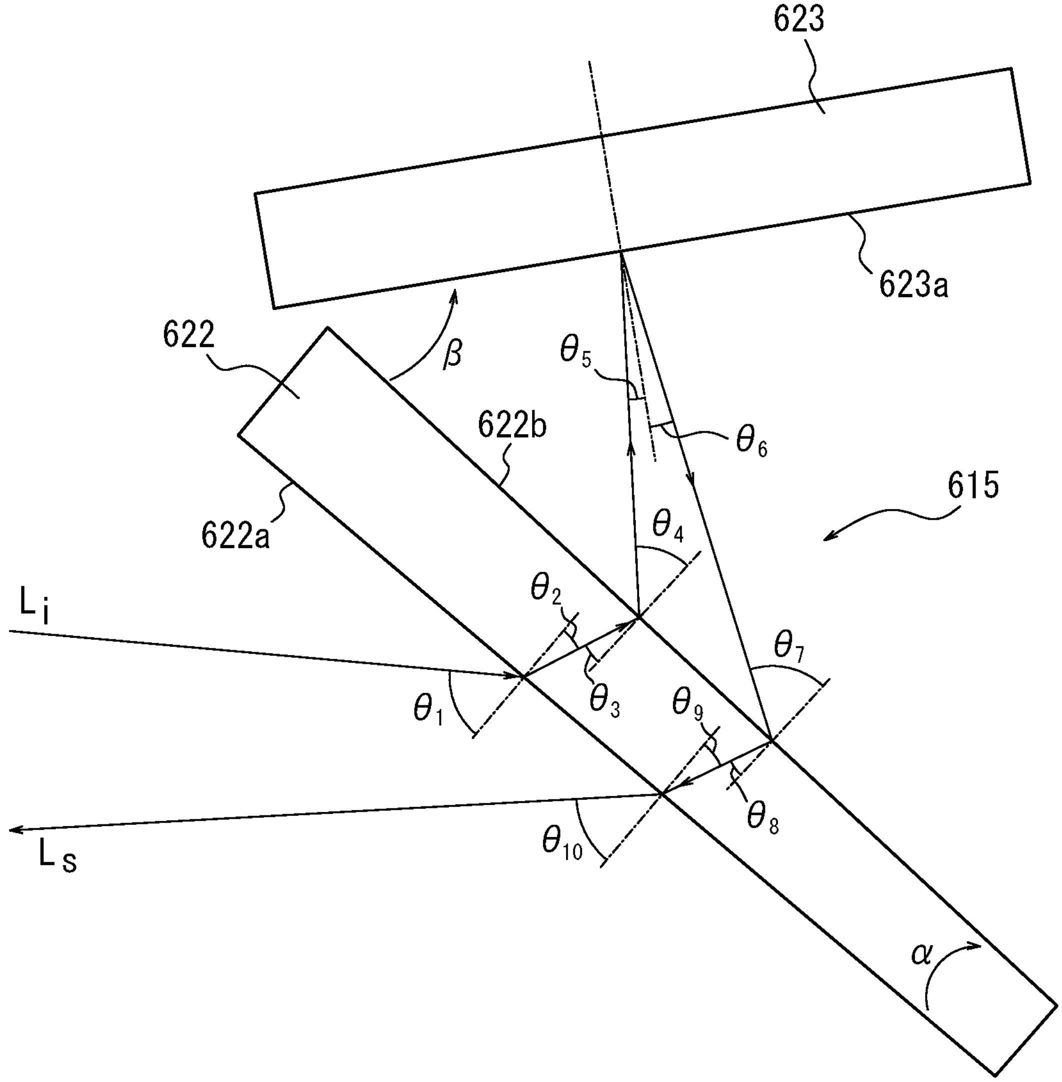
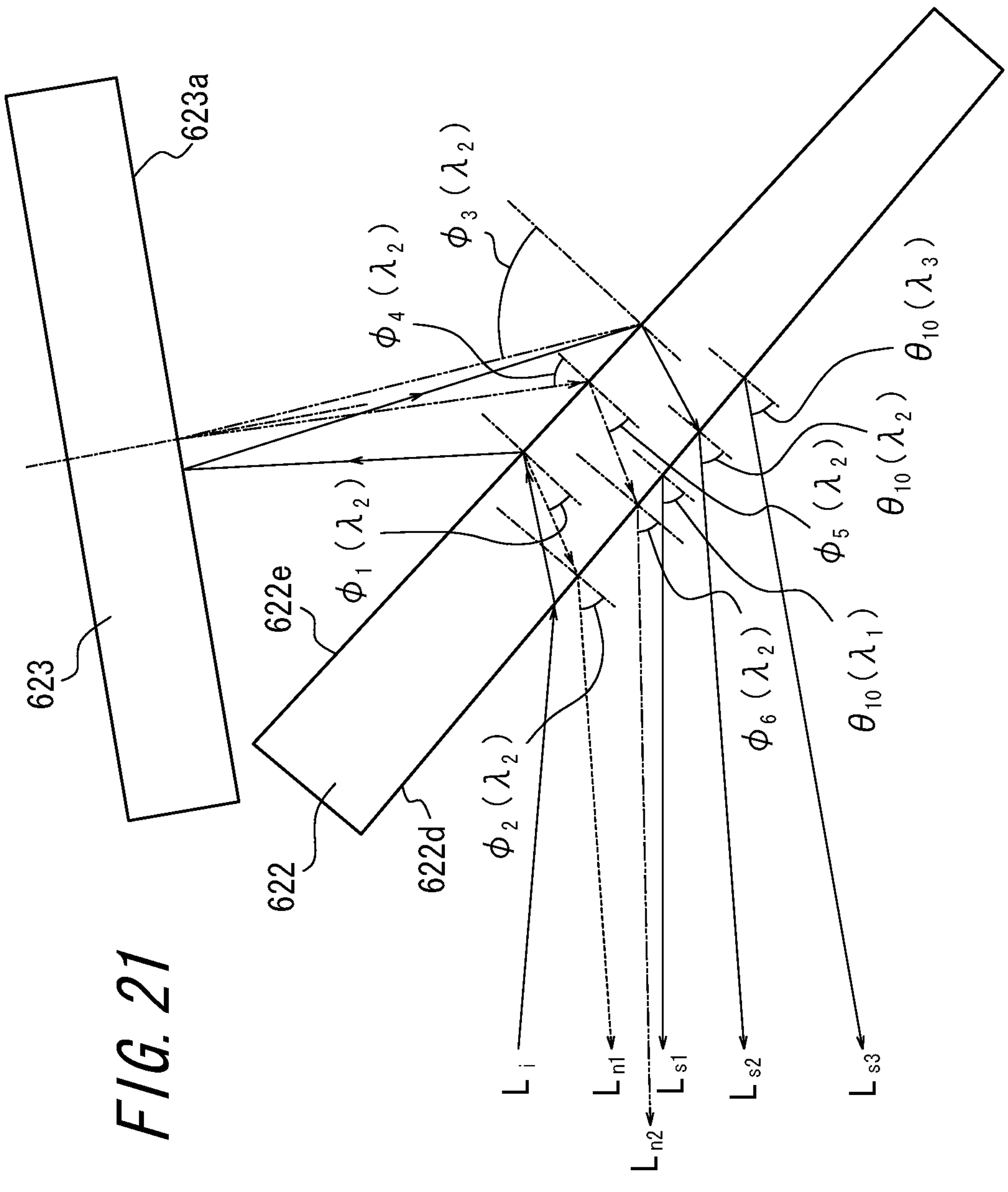


FIG. 20


623
623a
622
β
622b
θ_5
θ_6
615
622a
θ_4
L_i
θ_2
θ_7
θ_1
θ_3
θ_9
θ_8
L_s
θ_{10}
α



623a
623
622e
622
622d
$\phi_3(\lambda_2)$
$\phi_4(\lambda_2)$
$\theta_{10}(\lambda_3)$
$\theta_{10}(\lambda_2)$
$\phi_5(\lambda_2)$
$\phi_1(\lambda_2)$
$\phi_6(\lambda_2)$
$\theta_{10}(\lambda_1)$
$\phi_2(\lambda_2)$
L_i
L_{n1}
L_{n2}
L_{s1}
L_{s2}
L_{s3}

FIG. 21

FIG. 22A

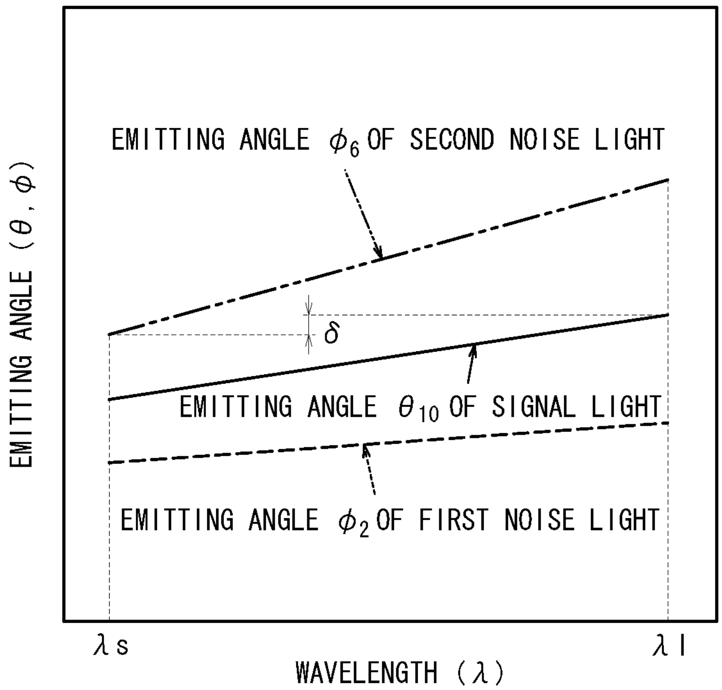


FIG. 22B

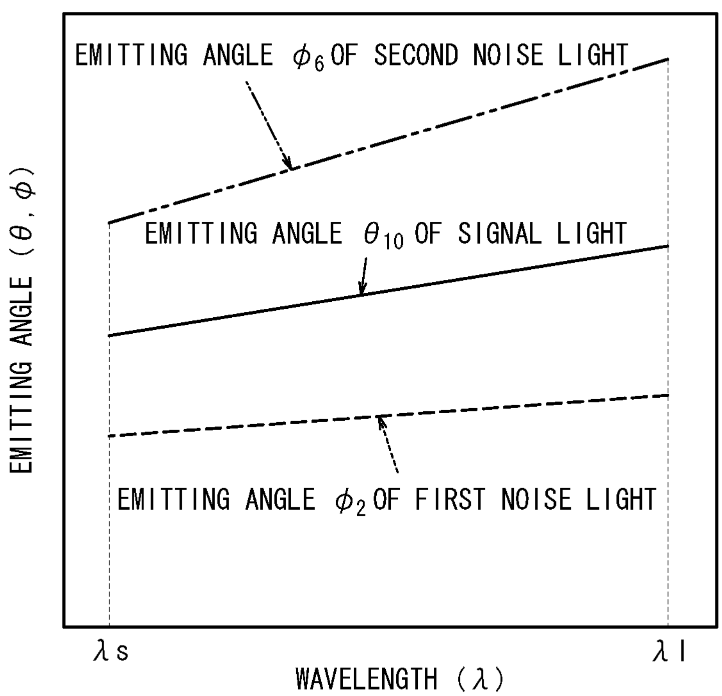


FIG. 23

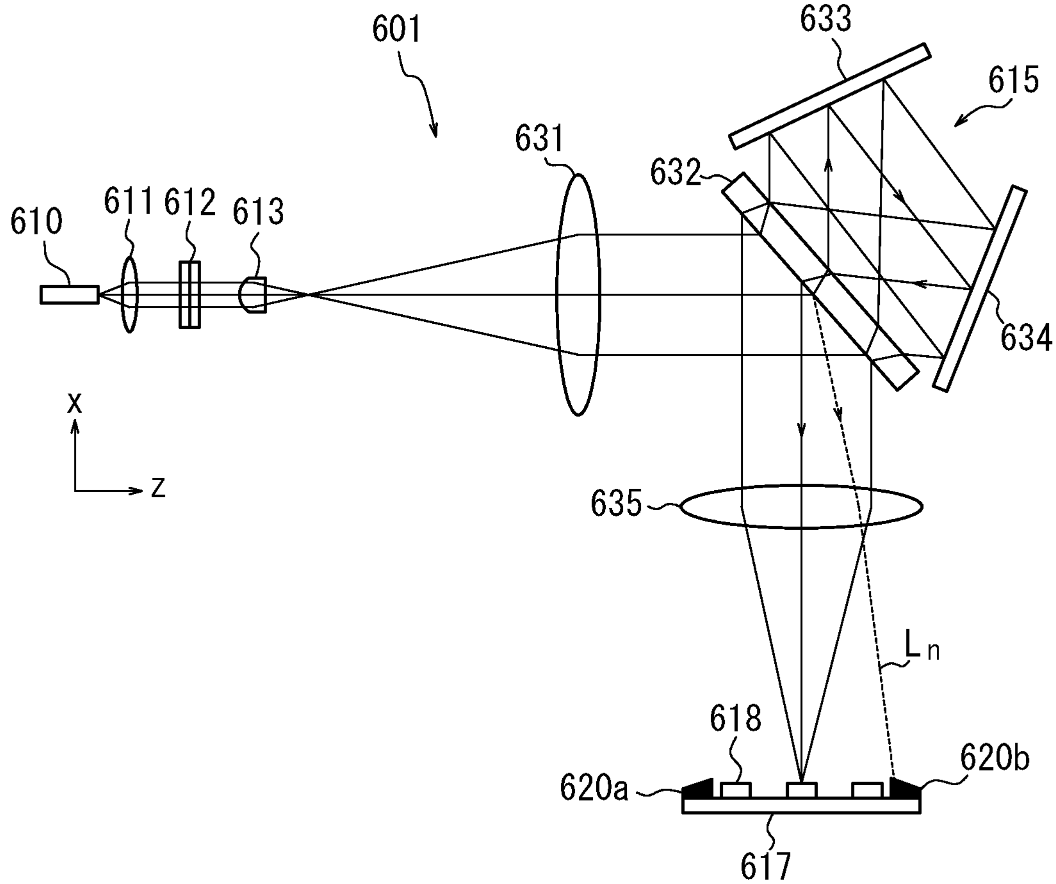

601
633
615
631
632
610
611
612
613
634
X
Z
635
L_n
618
620a
620b
617

FIG. 24

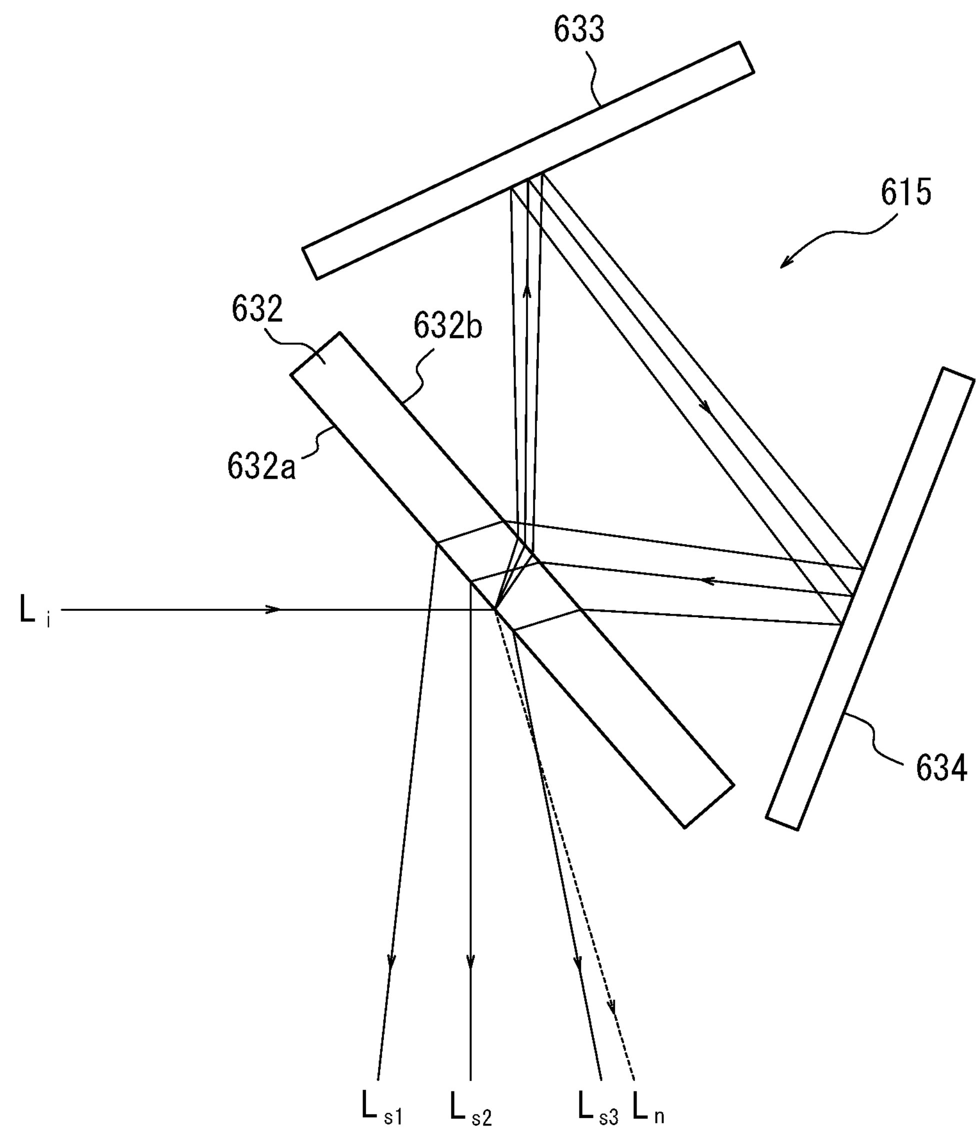


FIG. 25

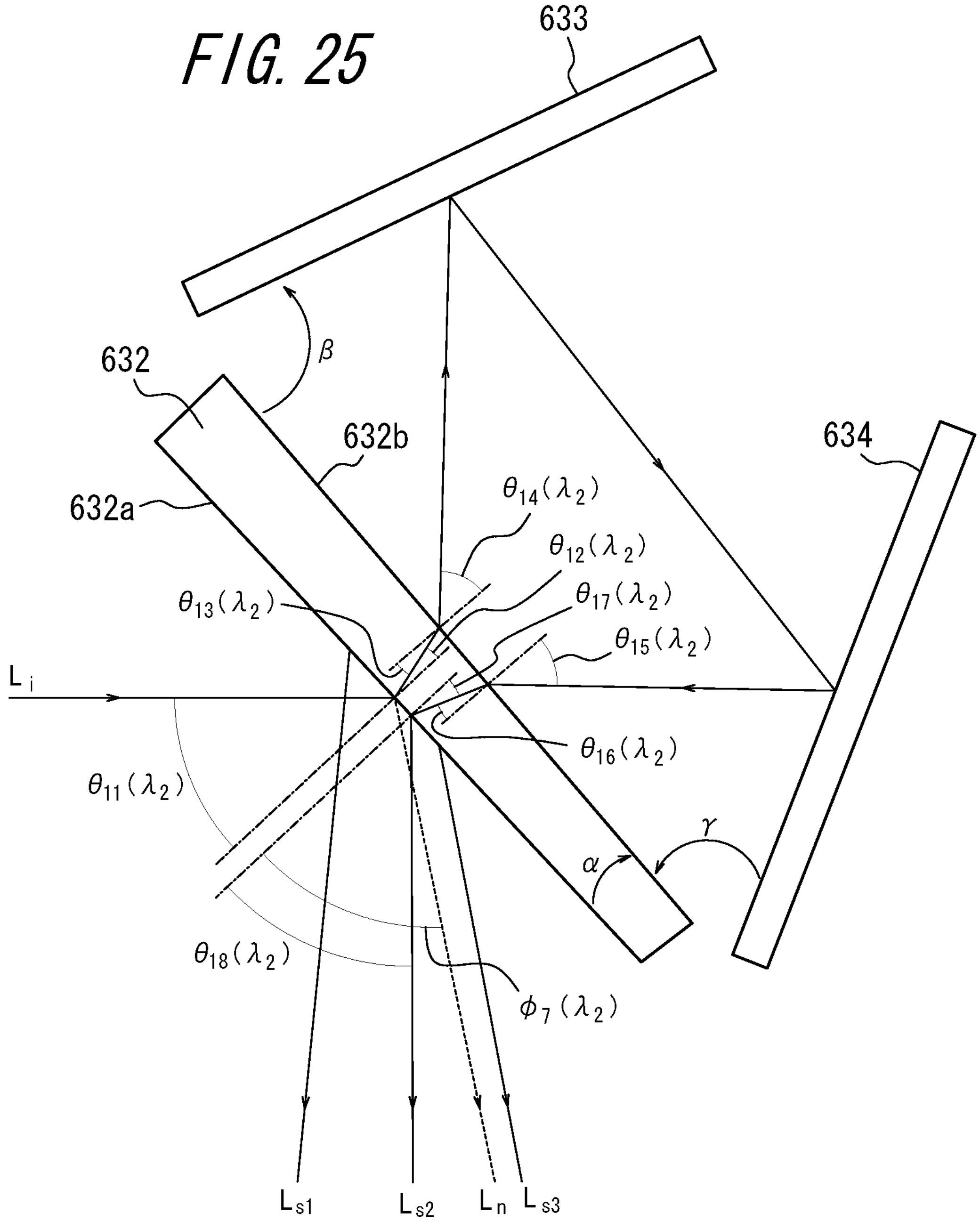

633
632
632b
632a
634
β
α
γ
θ14(λ2)
θ12(λ2)
θ17(λ2)
θ13(λ2)
θ15(λ2)
θ16(λ2)
θ11(λ2)
θ18(λ2)
φ7(λ2)
Li
Ls1
Ls2
Ln
Ls3

FIG. 26

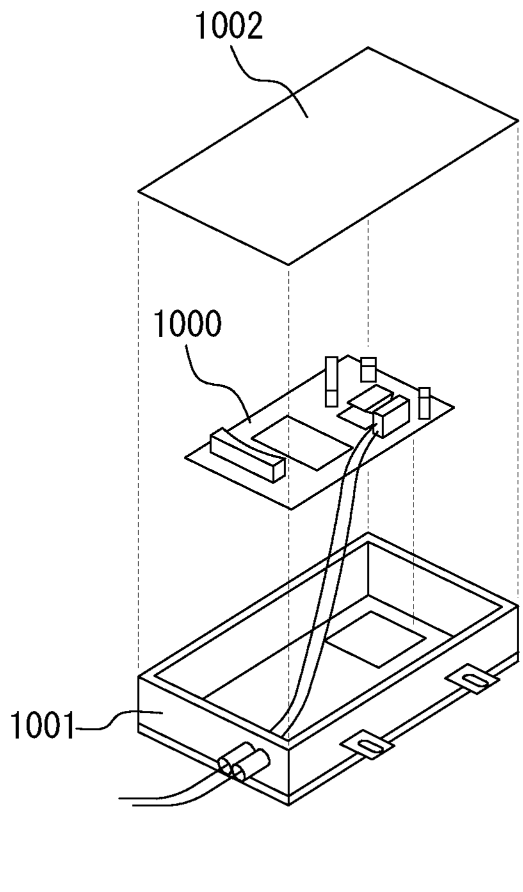
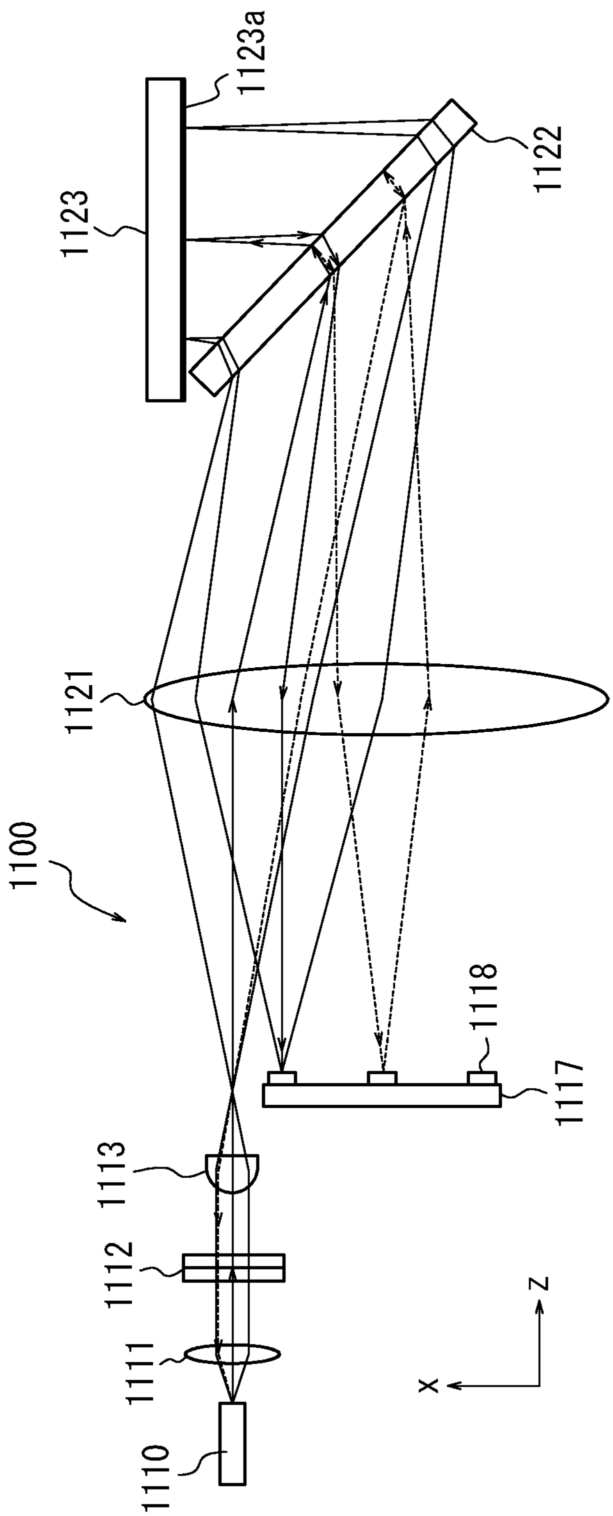


FIG. 27



OPTICAL UNIT FOR WAVELENGTH SELECTING SWITCH AND WAVELENGTH SELECTING SWITCH

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a Continuing Application based on International Application PCT/JP2012/001323 filed on Feb. 27, 2012, which in turn, claims the benefit of priority from the prior Japanese Patent Application No. 2011-045713 filed on Mar. 2, 2011, Japanese Patent Application No. 2011-066160 filed on Mar. 24, 2011, and Japanese Patent Application No. 2011-066541 filed on Mar. 24, 2011, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to an optical unit for a wavelength selecting switch and the wavelength selecting switch.

The wave length selecting switch has a function of dispersing light on the basis of a frequency so as to output. The wavelength selecting switch is provided, for example, in a node which connects ring networks, and a metro network is constructed by connecting a plurality of ring networks. At this time, the wavelength selecting switch operates so as to switch a route of the incident light from an optical fiber constructing the ring network on the basis of the frequency.

BACKGROUND ART

Conventionally, as the wavelength selecting switch, there has been proposed a wavelength selecting switch in which a dispersive element, a plurality of optical parts, and a micro electro mechanical systems (MEMS) array (a mirror array) are accommodated in a state of being sealed in an internal portion of a casing (for example, refer to patent document 1). In the wavelength selecting switch mentioned above, if a light path is appropriately adjusted so as to be fixed and the casing is sealed in a manufacturing stage, fluctuation of refraction factor due to change of air pressure can be avoided, and the light path within the casing is appropriately maintained.

FIG. **26** is an exploded perspective view showing an outline structure of a wavelength selecting switch disclosed in patent document 1. In the wavelength selecting switch, various optical parts constructing an optical system of the wavelength selecting switch are mounted to a flat optical bench **1000**. Further, a casing **1001** is hermetically sealed by fixing the optical bench **1000** to which the optical system is mounted, to a bottom portion within the casing **1001**, and covering an upper opening portion of the casing **1001** by a lid **1002**.

Further, the wavelength selecting switch generally employs an apparatus which is provided with at least one input port, at least one output port, a dispersing portion, a converging portion and a deflecting portion. In this apparatus, the wavelength multiplexed light input into the wavelength selecting switch from one optical fiber of the input port is dispersed per wavelength by the dispersion portion such as a diffraction grating, and is converged into a different mirror element in the deflecting portion such as the MEMS mirror array. The light converged into each of the mirror elements is deflected and output in a predetermined output port direction per wavelength by controlling each of the mirror elements to a predetermined angle. Generally, the mirror array is constructed by mirror elements which are arranged in one line in a direction of x axis on a plane which is approximately vertical to the incident light. A light flux wavelength dispersed in the direction of x axis is incident on the mirror element. A wavelength of the light coming to a center of each of the mirror elements is preferably close to a predetermined value which is defined by a standard.

Further, as the dispersing portion, there has been various structures for obtaining a great dispersion by a reduced number of optical parts. For example, in a wavelength selecting switch having a dispersion portion of so-called Littman-Metcalf configuration in which the diffraction grating and the mirror are arranged in a mutually inclined manner, a great dispersing effect is obtained by converting the wavelength multiplexed light into parallel light by the lens or the mirror so as to enter into the diffraction grating, temporarily bringing the light dispersed by the diffraction grating to the mirror so as to be reflected, and thereafter again entering into the diffraction grating (for example, refer to patent document 2).

Patent Document 1: JP-A-2009-145887

Patent Document 2: U.S. Pat. No. 7,630,599

SUMMARY OF THE INVENTION

In the case that the mirror array is bonded and fixed to the casing, there is a risk that a position of the mirror array is displaced about 10 μm entirely at a coagulating time of a pressure sensitive adhesive. Further, since the deflecting portion such as the mirror array provided in the wavelength selecting switch is structured movable, the deflecting portion has a higher risk of damage and failure in comparison with the other optical elements provided in the inner portion of the casing of the wavelength selecting switch. Therefore, in design of the wavelength selecting switch, it is thinkable to facilitate replacement and repair at a time of the damage and the failure, as the structure which is provided with the mirror array in the outer portion of the casing. Further, it is thinkable to design the other optical systems than the mirror array as an optical unit for the wavelength selecting switch hermetically embedded in the casing, and detachably mount the mirror array to the optical unit for the wavelength selecting switch, thereby serving as the wavelength selecting switch.

In the structure mentioned above, the disperse element, a plurality of optical parts and the mirror array are not sealed in one casing in a state of being appropriately light path adjusted at the manufacturing time, as is different from the wavelength selecting switch described in the patent document 1. In other words, the wavelength selecting switch mentioned above is structured such that the dispersion portion and the optical system for converging are sealed in the casing, and the mirror array is attached to the outer portion of the casing. Therefore, in the wavelength selecting switch mentioned above, it is desired to adjust the dispersing portion and the optical system for converging (hereinafter, the dispersing portion is called as "optical system in casing" in conjunction with the optical system for converging) which are sealed in the casing, in relation to the mirror array which is provided in the outer portion of the casing.

It is preferable to provide a wavelength selecting switch which can solve the problem mentioned above and can adjust the light path of the optical system in the casing of the wavelength selecting switch from the outer portion of the casing.

Further, it is necessary for the wavelength selecting switch to compensate a stable operation in temperature and humidity ranges of the specification. Accordingly, it is important to precisely arrange various optical parts constructing the optical system in the optical bench **1000**. However, if the optical bench **1000** is thin, distortion or deformation is generated in the optical bench **1000** by attachment of the optical parts, and it becomes hard to arrange the optical parts at a desired precision. Further, even if the optical parts can be arranged at the desired precision, in the case that the optical bench **1000** is thin, the distortion or the deformation is generated in the same manner in the optical bench **1000** by fixing the optical bench **1000** to the bottom portion of the casing **1001**, for example, by general screw fastening and it becomes hard to maintain an arrangement precision of the optical parts. Therefore, the optical bench **1000** requires certain degree of thickness.

On the other hand, the wavelength selecting switch is required to be thinned the casing **1001**. Here, in the structure in FIG. **26**, the thickness of the casing **1001** needs to cover at least total of a thickness of the optical bench **1000**, a clearance for avoiding interference between the optical bench **1000** and the casing **1001**, a height of the optical parts, and a clearance for avoiding interference between the optical parts and the lid **1002**. Accordingly, if the optical bench **1000** is thin, it becomes hard to thin the casing **1001**.

As mentioned above, the convention wavelength selecting switch has a trade-off relationship between the thickness of the optical bench **1000** and the thinning of the casing **1001**, and it is hard to satisfy both.

It is preferable to provide a wavelength selecting switch which can solve the problem and can thin the casing while securing the thickness of the optical bench.

Further, in the dispersing portion of Littman-Metcalf configuration, a transmission type diffraction grating is employed, and the dispersing portion transmits a diffraction grating surface of the diffraction grating two times. However, as a result of study by the inventors of the present invention, a noise light of a transmission diffraction light and a reflection diffraction light having different order may be generated in the diffraction grating surface, in addition to a transmission diffraction light (normal light) of a desired order based on the design of diffraction grating. If the noise light enters into the deflecting portion, and is coupled to an output port from which the normal light in the same wavelength band is output, an undesired output level fluctuation (ripple) may be generated due to a wavelength dependency of light path difference between the noise light and the normal light.

FIG. **27** is a view showing an outline structure of a wavelength selecting switch **1100** having a dispersing portion of Littman-Metcalf configuration. The dispersing portion is constructed by a diffraction grating **1122** and a mirror **1123**. In the wavelength selecting switch **1100**, an input light input from any input and output port of the input and output portion **1100** comes to a parallel light by a micro lens **1111** as shown its light path by a solid line, is temporarily converged by cylindrical lenses **1112** and **1113**, and thereafter enters as a parallel beam into a diffraction grating **1122** by a lens **1121**. The input light entering into the diffracting grating **1122** is exposed to a primary diffraction by the diffraction grating **1122** so as to transmit and be dispersed into lights per wavelength, is reflected by the mirror **1123** so as to be returned, and is exposed to a primary diffraction by the diffraction grating **1122** so as to transmit and be further dispersed. The light dispersed by the diffraction grating **1122** is converged per wavelength on a deflecting element (mirror) **1118** of a deflecting portion **1117** by the lens **1121**. The light per wavelength is reflected at different angles per wavelength by the deflecting element **1118**, is returned the light path until being reflected by the deflecting element **1118**, and is output from a predetermined any output port of the input and output portion **1110**.

However, if a part of the input light from the lens **1121** is primarily diffracted and reflected at a time when the input light from the lens **1121** first enters into the diffraction grating

surface of the diffraction grating **1122**, the input light comes to the noise light passing through a light path which is different from the normal light mentioned above. As shown by a broken line in FIG. **27**, if a part of the noise light enters into any deflecting element **1118**, the reflected light thereof is coupled to any output port at a higher coupling efficiency than the other noise components. In the case that the output port from which the noise light is output is the same port as the output port from which the normal light having the same wavelength is output, a ripple is generated due to interference between the normal light and the noise light.

Further, in the same manner, in the other structures of the dispersing portion, a light path difference caused by diffraction (including transmission and reflection) of a desired order and a different order in the diffraction grating deteriorates a transmission band characteristic of the wavelength selecting switch.

It is preferable to solve the problem and prevent the transmission band characteristic from being deteriorated due to an undesired diffraction on the diffraction grating of the wavelength selecting switch.

Accordingly, an object of the present invention made by taking the above circumstance into consideration is to provide a wavelength selecting switch having an excellent characteristic which solves at least one of the problems.

An optical unit for a wavelength selecting switch according to the present invention achieving the object mentioned above is provided with at least one input port, a dispersing portion which disperses a wavelength of an input light input from the input port, a converging element which converges the light dispersed by the dispersing portion, at least one output port, a light path compensating portion which shifts the light dispersed by the dispersing portion, an adjusting portion which changes a shift amount by the light path compensating portion, and a casing which seals the input port, the dispersing portion, the converging element, the output port and the light path compensating portion, wherein the casing has a transparent portion which is optically transparent at a position into which the light converged by the converging element enters, the adjusting portion is arranged in an outer portion of the casing, and the light path compensating portion can be controlled from the outer portion of the casing by the adjusting portion.

Accordingly, the light path of the optical system within the casing of the wavelength selecting switch can be adjusted from the outer portion of the casing.

Further, in the optical unit for the wavelength selecting switch according to the present invention, the light path compensating portion is preferably arranged in the light path between the input port and the dispersing portion.

Further, in the optical unit for the wavelength selecting switch according to the present invention, the light path compensating portion is preferably arranged in the light path between the dispersing portion and the transparent portion.

Further, in the optical unit for the wavelength selecting switch according to the present invention, the light path compensating portion is preferably provided with an optical element for compensating light path, and an actuator for driving the optical element, and the adjusting portion preferably adjusts the shift amount by driving the actuator.

Further, in the optical unit for the wavelength selecting switch according to the present invention, the dispersing portion is preferably constructed by a Littman-Metcalf configuration having a transmission type dispersing element and a reflecting element, the reflecting element preferably constructs the light path compensating portion, and the adjusting portion preferably adjusts the shift amount by displacing the reflecting element.

Further, in the optical unit for the wavelength selecting switch according to the present invention, the light path compensating portion is preferably provided with an electro-optic device, and the adjusting portion preferably adjusts the shift amount by controlling a voltage applied to the electro-optic device.

Further, in the optical unit for the wavelength selecting switch according to the present invention, the casing is preferably provided with a nonmagnetic material portion at least partly, the light path compensating portion is preferably provided with an optical element for compensating the light path, and a magnetic material or a magnet attached to the optical element, and the nonmagnetic material portion is preferably provided with a magnet or a magnetic material which adjusts the shift amount by displacing the optical element by a magnetic force in cooperation with the magnetic material or the magnet via the nonmagnetic material portion.

Further, in the optical unit for the wavelength selecting switch according to the present invention, the optical element for compensating the light path is preferably provided with parallel flat plates.

Further, in the optical unit for the wavelength selecting switch according to the present invention, the casing preferably has a transparent window for fixing the light path compensating portion to the casing by an ultraviolet light curable pressure sensitive adhesive.

A wavelength selecting switch according to the present invention achieving the object mentioned above is provided with any one optical unit for the wavelength selecting switch mentioned above, and a deflecting portion which is attached to an outer side of the casing and deflects the light converged by the converging element.

Further, in the wavelength selecting switch according to the present invention, the light path compensating portion preferably shifts an incident position of the light dispersed by the dispersing portion in relation to the deflecting portion.

Further, the invention of a wavelength selecting switch according to the present invention achieving the object mentioned above is provided with at least one input port, a dispersing portion which disperses a wavelength of an input light entering from the input port, a converging element which converges the light dispersed its wavelength by the dispersing portion, a deflecting portion which deflects the light converged by the converging element, at least one output port which outputs the light deflected by the deflecting portion as an output light, an optical bench which supports at least the dispersing portion and the converging element, and a casing which accommodates and retains the optical bench, wherein the optical bench is attached in such a manner that a support surface supporting the dispersing portion and the converging element intersects a surface having the greatest project area of the casing.

Accordingly, it is possible to provide the wavelength selecting switch which can achieve the thinning of the casing while securing the thickness of the optical bench.

The input port and the output port are preferably arranged linearly, the deflecting portion is preferably supported by a support portion which protrudes out of the support surface of the optical bench among the input port, the output port and the converging element, and a light transmission portion transmitting the input light and the output light is preferably formed in the support portion.

A primary converging lens forming a primary converging point is preferably provided among the input port, the output port and the converging element, the support portion is preferably arranged in such a manner that the light transmitting portion is positioned at the primary converging point or in the vicinity thereof, and the dispersing portion, the converging element and the deflecting portion are preferably arranged in such a manner that the input light from the input port is dispersed by the dispersing portion through the primary converging lens and the converging element, and the dispersed light is deflected by the deflecting portion through the converging element, and is output as the output light from the output port through the dispersing portion and the converging element.

Further, the invention of a wavelength selecting switch achieving the object mentioned above is provided with at least one input port which inputs a wavelength multiplexed light, a dispersing portion which disperses the wavelength multiplexed light input from the input port, a converging portion which converges the light dispersed by the dispersing portion per wavelength, a deflecting portion which can independently deflect the light converged by the converging portion per wavelength, and at least one output port which outputs the light deflected by the deflecting portion, wherein the dispersing portion includes a diffraction grating, and the light diffracted at a desired order by the diffraction grating and a noise light diffracted at least at a different order from the desired order, or in a different reflection or transmission mode are structured such that output angle ranges from the dispersing portion do not overlap.

Accordingly, since the light diffracted at the desired order by the diffraction grating and the noise light diffracted at least at the different order from the desired order, or in the different reflection or transmission mode are structured such that the output angle ranges from the dispersing portion do not overlap, it is possible to prevent the transmission band characteristic from being deteriorated by the undesired diffraction on the diffraction grating surface of the wavelength selecting switch.

The diffraction grating is preferably constructed by a transmission type diffraction grating, and the noise light is preferably constructed by the light reflected by the diffraction grating surface of the diffraction grating. Here, the reflected light includes not only the regular reflected light but also the reflection diffraction light.

Further, it is preferable that the dispersing portion further includes a reflection element, the wavelength multiplexed light input from the input port is structured such as to transmit the diffraction grating by a m-order diffraction, be reflected by the reflection element, and further transmit the diffraction grating by the m-order diffraction, and the noise light is constructed by a first noise light which is reflected by the m-order diffraction at a time when the wavelength multiplexed light enters into the diffraction grating surface of the diffraction grating first time, and a second noise light which is reflected by the m-order diffraction at a time when the light transmitting the diffraction grating enters into the diffraction grating second time after being reflected by the reflection element, is further reflected by the reflection element and transmits the diffraction grating by the m-order diffraction, in which m is the other integers than 0.

Further, in the case of setting the maximum value and the minimum value of a wavelength λ of the wavelength multiplexed light to λ_1 and λ_s, and setting outgoing angles of the light diffracted by the desired order, the first noise light and the second noise light from the dispersing portion with regard to the wavelengths λ of the wavelength multiplexed lights respectively to $\theta_o(\lambda)$, $\phi_{o1}(\lambda)$ and $\phi_{o2}(\lambda)$, it is preferable to satisfy the following expression.

$$\max_{\lambda_s \le \lambda \le \lambda_1} \phi_{o1}(\lambda) < \min_{\lambda_s \le \lambda \le \lambda_1} \theta_o(\lambda) \text{ or } \max_{\lambda_s \le \lambda \le \lambda_1} \theta_o(\lambda) < \min_{\lambda_s \le \lambda \le \lambda_1} \phi_{o1}(\lambda)$$

and

$$\max_{\lambda_s \le \lambda \le \lambda_1} \phi_{o2}(\lambda) < \min_{\lambda_s \le \lambda \le \lambda_1} \theta_o(\lambda) \text{ or } \max_{\lambda_s \le \lambda \le \lambda_1} \theta_o(\lambda) < \min_{\lambda_s \le \lambda \le \lambda_1} \phi_{o2}(\lambda)$$

Alternatively, the dispersing portion may include a first reflection element and a second reflection element, the wavelength multiplexed light input from the input port may be structured such as to transmit the diffraction grating by the m-order diffraction, be sequentially reflected by the first reflection element and the second reflection element, and further transmit the diffraction grating by -m-order diffraction, and the noise light may be constructed by a noise light which is regularly reflected at a time when the wavelength multiplexed light enters into the diffraction grating surface of the diffraction grating first time, in which m is the other integers than 0.

In this case, in the case of setting the maximum value and the minimum value of the wavelength λ of the wavelength multiplexed light to λ_1 and λ_s, and setting the outgoing angles from the dispersing portion of the light diffracted by the desired order and the noise light with regard to the wavelengths λ of the wavelength multiplexed lights respectively to $\theta_o(\lambda)$ and $\phi_o(\lambda)$, it is preferable to satisfy the following expression.

$$\max_{\lambda_s \le \lambda \le \lambda_1} \phi_o(\lambda) < \min_{\lambda_s \le \lambda \le \lambda_1} \theta_o(\lambda) \text{ or } \max_{\lambda_s \le \lambda \le \lambda_1} \theta_o(\lambda) < \min_{\lambda_s \le \lambda \le \lambda_1} \phi_o(\lambda)$$

Further preferably, the deflecting portion is provided with a deflecting element which deflects the converged light, and a noise light suppressing portion which suppresses the outgoing of the noise light to the output port is provided in a portion in which the deflecting element is not arranged in the deflecting portion.

The noise light suppressing portion may be constructed by a light absorbing member which absorbs the noise light, and may have a reflecting surface which reflects the noise light in a direction which does not reflects the noise light.

Further, it is further preferable that the incident angle of the wavelength multiplexed light to the dispersing portion does not lap over the outgoing angle range of the noise light from the dispersing portion.

According to the present invention, the wavelength selecting switch having an excellent characteristic can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a plan view showing an outline structure of a wavelength selecting switch according to a first embodiment.

FIG. **1**B is a side elevational view describing the outline structure of the wavelength selecting switch according to the first embodiment.

FIG. **2**A is a view for describing an outline structure of a light path compensating portion in the wavelength selecting switch according to the first embodiment.

FIG. **2**B is a view for describing the outline structure of the light path compensating portion in the wavelength selecting switch according to the first embodiment.

FIG. **2**C is a view for describing a function of the light path compensating portion according to the first embodiment.

FIG. **3**A is a plan view showing an outline structure of a wavelength selecting switch according to a second embodiment.

FIG. **3**B is a side elevational view showing the outline structure of the wavelength selecting switch according to the second embodiment.

FIG. **3**C is a view for describing a function of a light path compensating portion according to the second embodiment.

FIG. **4**A is a plan view showing an outline structure of a wavelength selecting switch according to a third embodiment.

FIG. **4**B is a side elevational view describing the outline structure of the wavelength selecting switch according to the third embodiment.

FIG. **5**A is a view for describing an outline structure of a light path compensating portion according to the third embodiment.

FIG. **5**B is a view for describing the outline structure of the light path compensating portion according to the third embodiment.

FIG. **5**C is a view for describing a function of the light path compensating portion according to the third embodiment.

FIG. **6** is a plan view showing an outline structure of a wavelength selecting switch according to a fourth embodiment.

FIG. **7**A is a view for describing an outline structure of a light path compensating portion according to the present embodiment.

FIG. **7**B is a view for describing the outline structure of the light path compensating portion according to the fourth embodiment.

FIG. **7**C is a view for describing the outline structure of the light path compensating portion according to the fourth embodiment.

FIG. **8**A is a view showing a modified example of the wavelength selecting switch according to the fourth embodiment.

FIG. **8**B is a view for describing an outline structure of a light path compensating portion according to a modified example shown in FIG. **8**A.

FIG. **9** is a view for describing a light flux adjusting method in the wavelength selecting switch according to the present invention.

FIG. **10**A is a view showing a structure of a substantial part of a wavelength selecting switch according to a fifth embodiment as seen from a wavelength dispersing direction by a dispersing portion.

FIG. **10**B is a view showing the structure of the substantial part of the wavelength selecting switch according to the fifth embodiment as seen from a direction which is orthogonal to the wavelength dispersing direction by the dispersing portion.

FIG. **11**A is a view showing one modified example of an optical base plate of the wavelength selecting switch according to the fifth embodiment.

FIG. **11**B is a view showing the other modified example of the optical base plate of the wavelength selecting switch according to the fifth embodiment.

FIG. **12**A is a view showing a structure of a substantial part of a wavelength selecting switch according to a sixth embodiment as seen from a wavelength dispersing direction by a dispersing portion.

FIG. **12**B is a view showing the structure of the substantial part of the wavelength selecting switch according to the sixth embodiment as seen from a direction which is orthogonal to the wavelength dispersing direction by the dispersing portion.

FIG. **13**A is a view showing a structure of a substantial part of a wavelength selecting switch according to a seventh embodiment as seen from a wavelength dispersing direction by a dispersing portion.

FIG. **13**B is a view showing the structure of the substantial part of the wavelength selecting switch according to the seventh embodiment as seen from a direction which is orthogonal to the wavelength dispersing direction by the dispersing portion.

FIG. **14** is a view showing a modified example of the seventh embodiment.

FIG. **15**A is a side elevational view describing a basic structure of the wavelength selecting switch.

FIG. **15**B is a top elevational view describing the basic structure of the wavelength selecting switch.

FIG. **16** is a top elevational view showing an outline structure of a wavelength selecting switch according to an eighth embodiment.

FIG. **17** is a top elevational view describing light paths of a normal light and a noise light in a dispersing portion in FIG. **16**.

FIG. **18** is a side elevational view showing a structure of a dispersing element in FIG. **16**.

FIGS. **19**A and **19**B are views describing a joint between a transmission type diffraction grating of the dispersing element in FIG. **18** and a wedge prism.

FIG. **20** is a view describing an angular relationship between an optical member constructing the dispersing portion in FIG. **16** and the normal light passing through the dispersing portion.

FIG. **21** is a view describing an angular relationship between a noise light generated in the dispersing portion in FIG. **16** and the normal light.

FIG. **22**A is a view showing a relationship of an outgoing light in the normal light and the noise light in relation to a wavelength (λ) in the case that interference is generated between the normal light and the noise light.

FIG. **22**B is a view showing a relationship of an outgoing angle (θ, ϕ) in the normal light and the noise light in relation to the wavelength (λ) in the eighth embodiment.

FIG. **23** is a top elevational view showing an outline structure of a wavelength selecting switch according to a ninth embodiment.

FIG. **24** is a top elevational view describing light paths of the normal light and the noise light in a dispersing portion in FIG. **23**.

FIG. **25** is a view describing an angular relationship between the noise light generated in the dispersing portion in FIG. **23** and the normal light.

FIG. **26** is an exploded perspective view showing an outline structure of a conventional wavelength selecting switch.

FIG. **27** is a view showing an outline structure of a wavelength selecting switch having a dispersing portion of Littman-Metcalf configuration.

MODE FOR CARRYING OUT THE INVENTION

A description will be given below of embodiments according to the present invention with reference to the accompanying drawings.

First Embodiment

FIG. **1**A is a plan view showing an outline structure of a wavelength selecting switch **100** according to a first embodiment of the present invention. FIG. **1**B is a side elevational view describing the outline structure of the wavelength selecting switch **100** according to the present embodiment. In FIGS. **1**A and **1**B, for the purpose of clarifying, each of light fluxes is shown by a center line, and in at least one light fluxes which are dispersed by a dispersing portion **112**, the light flux having a representative wavelength is shown by the center line.

The wavelength selecting switch **100** according to the present embodiment is provided with a casing **118** which hermetically embeds an optical fiber array **109**, an input and output port **110**, a lens array **111**, a first converging element **113***a*, a second converging element **113***b*, a dispersing portion **112**, a third converging element **113***c*, a mirror portion **114**, a compensating plate **116**, an actuator **117**, and a support body **122**, and has a window **119**, an optical unit **101** for a wavelength selecting switch which is provided with an adjusting portion **121**, and a deflecting portion casing **120** which embeds a deflecting portion **115**.

The optical fiber array **109** is constructed by at least two fibers. Further, the optical fiber array **109** extends into an inner portion of the casing **118** from an outer portion via a through hole provided in the casing **118**. Here, the through hole for passing the optical fiber array **109**, the through hole being formed in the casing **118** and the optical fiber array **109** are arranged with no gap. Accordingly, in spite of extension of the optical fiber array **109** to the inner portion from the outer portion of the casing **118**, the inner portion of the casing **118** keeps a sealed state.

The input and output port **110** is provided with at least one input port **110***a* and at least one output port **110***b*. The input port **110***a* inputs a wavelength multiplexed light signal from the optical fiber array **109** to an optical system of the wavelength selecting switch **100**. The output port **110***b* outputs a light signal from the optical system of the wavelength selecting switch **100** to the optical fiber array **109**.

In the present application, a description will be given on the assumption that the vicinity of a leading end of the optical fiber array **109** is particularly the input port **110***a* or the output port **110***b*. In other words, the input port **110***a* or the output port **110***b* is not limited to the other member than the optical fiber array **109**. Further, in FIG. **1**A, a portion of the input and output port **110** is made thicker in diameter than the portion of the optical fiber array **109**, however, the diameter is not limited to have difference actually.

Further, the number of ports constructing the input and output port **110** is set, for example, to be equal to or more than two, and more input and output ports can be provided, however, for convenience of explanation, only four representative input and output ports are illustrated in FIG. **1**B. Further, the number of the optical fibers constructing the optical fiber array **10** is changed in correspondence to the number of the ports constructing the input and output port **110**. Further, it is possible to appropriately design which input and output ports are used for inputting or outputting. In other words, only one input and output port may be used for inputting and the other input and output ports may be used for outputting, or a plurality of ports for inputting and a plurality of ports for outputting may be provided.

The lens array **111** is provided with a plurality of spherical or aspherical micro lenses for converging the light flux returning from the deflecting portion **115** to the input and output port **110** as well as making the light flux from the input and output port **110** parallel lights. Each of the micro lenses constructing the lens array **111** forms a pair with each of the ports constructing the input and output port **110**.

The first converging element **113***a* converges a light flux from each of the micro lenses of the lens array **111** into one point, and distributes the light flux turning back from the deflecting portion **115** to each of the micro lenses of the lens array **111**.

The compensating plate **116** is arranged between the first converging element **113***a* and the second converging element **113***b*. The compensating plate **116** is driven by the actuator **117** so as to compensate the light path. The light path compensating portion is constructed by the compensating plate **116** and the actuator **117**. The light path compensating portion shifts the light dispersed by the dispersing portion **112**. Specifically, the light path compensating portion shifts a converging position of the light flux entering into the deflecting portion **115** arranged in the outer portion of the casing **118** in relation to the deflecting portion **115**. A description will be given later of details of the light path compensating portion.

The second converging element **113***b* makes the light flux converged into one point by the first converging element **113***a* parallel lights, and converges the light flux turning back from the deflecting portion **115** to one point.

The dispersing portion **112** disperses per wavelength (wavelength disperses) the light flux which is made parallel by the second converging element **113***b*, and uniforms a forward moving direction of the light flux turning back from the deflecting portion **115** so as to input to the second converging element **113***b*. The dispersing portion **112** is constructed, for example, by a transmission type dispersing element (grating). Further, the dispersing portion **112** may be a Littman-Metcalf configuration type structure which is combined by the dispersing element and a mirror. Further, in this embodiment, the transmission type dispersing element is used, however, a reflection type diffraction grating, Grism, and a super prism may be used without being limited to the transmission type dispersing element.

The third converging element **113***c* converges the light flux dispersed by the dispersing portion **112** on the deflecting portion **115**. Further, the third converging element **113***c* collimates the light flux turning back from the deflecting portion **115** so as to make the light flux enter into the dispersing portion **112**.

The mirror portion **114** is structured such as to reflect the light from the converging element **113***c* so as to conduct to the deflecting portion **115** via the window **119**. Since the deflecting portion **115** is not provided on the forward moving direction of the light from the converging element **113***c*, the mirror portion **114** is necessary, however, the present embodiment is not limited to this aspect. For example, in the case that the deflecting portion **115** is provided on the forward moving direction of the light from the converging element **113***c*, the mirror **114** can be omitted.

The deflecting portion **115** has one or more deflecting element which deflects at least one light flux converged by the third converging element **113***c* at different angles, reflects the light flux from the third converging element **113***c* at a different angle from the incident angle, and turns back the light flux to the third converging element **113***c*.

The deflecting portion **115** is constructed, for example, a liquid crystal on silicon (LOCS) which is a MEMS mirror array or a reflection type liquid crystal display panel. In the case that the deflecting portion **115** is the MEMS mirror array, the deflecting portion **115** is structured such that a plurality of micro mirrors corresponding to wavelengths are arranged like an array. Each of the micro mirrors is driven by a power supply from a cable (not shown), thereby changing an incline of the micro mirror itself and changing the forward moving direction of the light per wavelength. The number of the deflecting elements provided in the deflecting portion **115** is not particularly limited.

The light flux heading for the deflecting portion **115** and the light flux turning back from the deflecting portion **115** pass through each of the first, second and third converging elements **113***a*, **113***b* and **113***c*. In other words, the first, second third converging elements **113***a*, **113***b* and **113***c* serve as a converging element which converges the light flux, or a collimator element which makes the light flux from one point parallel lights, however, all of them is called as the converging element here.

The casing **118** hermetically embeds the input port **110**, the lens array **111**, the dispersing portion **112**, the first, second and third converging elements **113***a*, **113***b* and **113***c*, the mirror portion **114**, the light path compensating portion (the compensating plate **116** and the actuator **117**) and the other elements arranged within the casing. A conducting wire supplying power supply to the optical fiber array **109** and the actuator **117** gets out of the casing **118** via a seal member, for example. Accordingly, it is possible to adjust the light path compensating portion from the outer portion of the casing **18** while keeping a sealing performance of the inner portion of the casing **118**.

The window **119** constructs an optically transparent portion which is arranged at a position where the light converted by the third converge element **113***c* enters. Specifically, the window **119** is constructed by a transparent material which is formed in a part of the casing **118**, and transmits the light reflected in a direct downward direction by the mirror portion **114**. The window **119** is constructed, for example, by quartz. Further, in place of the window, a plate constructed by a transparent material may be provided in the casing **118**. In this case, a member arranged in the casing **118** can be attached onto the plate.

The deflecting portion casing **120** embeds the deflecting portion **115**. The deflecting portion casing **120** and the casing **118** are separate bodies, and the deflecting portion casing **120** can be later attached to the casing **118**. Further, the deflecting portion casing **120** is detachable in relation to the casing **118**, and if the deflecting portion **115***b* is in failure, a user can replace the deflecting portion casing **120**.

The casing **118** and the deflecting portion casing **120** may be fixed by a pressure sensitive adhesive, or may be fixed by a fixing member such as a screw. Further, the casing **118** and/or the deflecting member **120** may be provided with an attaching member as occasion demands.

The adjusting portion **121** changes a shift amount by the light path compensating portion (the compensating plate **116** and the actuator **117**). Specifically, the adjusting portion **121** drives the actuator **117** so as to adjust the shift amount of the incident position of the light dispersed by the dispersing portion **112** in relation to the deflecting portion **115**. In the case that the actuator **117** is constructed by a piezoelectric element, the adjusting portion **121** makes the piezoelectric element expand and contract by controlling voltage applied to the piezoelectric element. On the basis of the expansion and contraction of the piezoelectric element, the compensating plate **116** is rotated at a desired rotating angle, and the incident position of the light in relation to the deflecting portion **115** is shifted at a desired amount.

As described above, the light flux from the input port **110***a* passes through the lens array **111**, the first converging element **113***a*, the compensating plate **116**, the second converging element **113***b*, the dispersing portion **112**, the third converging element **113***c*, the mirror portion **114** and the window **119** sequentially, is reflected by the deflecting portion **115**, passes through absolutely the inverse route to the above, and returns to the output port **110***b*.

Next, a description will be given of an outline structure of the light path compensating portion with reference to FIGS. 2A and 2B. FIG. 2A is a view for describing the outline structure of the light path compensating portion. FIG. 2A is a view of the light path compensating portion as seen from a direction a in FIG. 1A. As mentioned above, the light path compensating portion is constructed by the compensating plate **116** and the actuator **117**. The compensating plate **116** is constructed, for example, by parallel flat plates. The parallel flat plates are comparatively inexpensive. The compensating plate **116** is supported by the support body **122**. The support body **122** is rotatable about a rotary shaft **123** which is fixed to the casing **118**. The actuator **117** is arranged so as to come into contact with an end portion of the support body **122** in an opposite side to the rotary shaft **123**. The actuator **117** is constructed, for example, by a piezoelectric element. Specifically, the piezoelectric element may be a laminated type PZT (lead zirconate titanate).

FIG. 2B is a view for describing the outline structure of the light path compensating portion. FIG. 2B is a view of the light path compensating portion as seen from a direction b in FIG. 1A. An elastic body **124** is arranged so as to come into contact with the support body **122**. Further, a stopper **125** is arranged so as to come into contact with the elastic body **124**. The actuator **117** is driven by the adjusting portion **121**, whereby the support body **122** rotationally moves in relation to the rotary shaft **123**. In the case that the actuator **117** is constructed by the piezoelectric element, the voltage applied to the piezoelectric element is changed, and the piezoelectric element expands and contracts in correspondence to the voltage so as to rotationally move the support body **122** in relation to the rotary shaft **123**. In correspondence to the rotation of the support body **122**, the incline of the compensating plate **116** changes.

A description will be given of the shift of the converged position of the light flux entering into the deflecting portion **115** on the basis of the rotation of the compensating plate **116** with reference to FIG. 2C. FIG. 2C is a view for describing a function of the light path compensating portion according to the first embodiment. In FIG. 2C, the light flux dispersed by the dispersing portion **112** is constructed only by one light flux having a specific wavelength, and shows the light flux heading for the deflecting portion **115**. The mirror portion **114** is omitted. By rotating the compensating portion **116**, an apparent position of a point A where the light flux entering into the second converging element diverges is shifted as shown by a dotted line. A shift amount dx can be approximated by the following expression.

$$dx = t\theta/n$$

where n is refraction factor of the compensating plate **116**, t is thickness and θ is rotating angle.

In other words, the shift amount dx is approximately in proportion to the rotating angle of the compensating plate **116**. If the second converging element **113***b* and the third converging element **113***c* are equal in focal distance, the shift amount of the point where the light flux is converged by the third converging element **113***c* becomes equal to the shift amount of the point A.

Accordingly, it is well known that the converging position of the light flux having the specific wavelength by the third converging element **113***c* is shifted on the deflecting element of the deflecting portion **115** by the rotation of the compensating plate **116**. Therefore, a whole of the light flux in the wavelength zone entering into the wavelength selecting switch **100** is shifted on most of the deflecting elements constructing the deflecting portion **115**.

As mentioned above, the wavelength selecting switch **100** and the optical unit **101** for the wavelength selecting switch according to the present embodiment can shift the position where the light enters into the deflecting portion **115**, by the light path compensating portion. Further, since the light path compensating portion is adjusted its shift amount by the adjusting portion **121** provided in the outer portion of the casing **118**, the light path of the optical system in the casing can be adjusted, even after assembling the wavelength selecting switch **100** and the optical unit **101** for the wavelength selecting switch so as to be hermetically embedded in the casing **118**. Accordingly, in the case that the deflecting portion casing **120** including the deflecting portion **115** is externally attached, in relation to the optical unit **101** for the wavelength selecting switch or the casing **118**, it is possible to adjust the optical system of the optical unit **101** for the wavelength selecting switch or the optical system embedded in the casing **118** in conformity to the deflecting portion **115**, even if the deflecting portion casing **120** slightly moves from the regular attaching position at the curing time of the pressure sensitive adhesive or the screwing time.

As a specific method of adjusting the light flux, for example, methods described below can be listed up. After externally attaching the deflecting portion casing **120** which embeds the deflecting portion **115** in relation to the optical unit **101** for the wavelength selecting switch or the casing **118**, the deflecting element of the deflecting portion **115** is inclined in such a manner that all the wavelengths are input to one output port **110***b*. The light signal output from one output port **110***b* is observed by a light spectrum analyzer via the optical fiber array **109**. Since the deflecting element of the deflecting portion **115** is discontinuous, the light having a wavelength of the discontinuous portion does not return, and a signal shown in FIG. **9** is observed. The wavelength of the light turning back from each of the deflecting elements of the deflecting portion **115** comes to a band of one channel. The wavelength at the center of the band is set to a center wavelength. The center wavelength is shifted by shifting the position where the light enters into the deflecting portion **115** by the light path compensating portion according to the method mentioned above. A state of the light path compensating portion is held in such a manner that the center wavelength of each of the channels becomes near the wavelength defined by the standard.

Further, in the present embodiment, since the light path compensating portion is arranged in the light path between the input and output port **110** and the dispersing portion **112**, it is possible to make a magnitude of the compensating plate **116** provided in the light path compensating portion comparatively small. This is because it is not necessary to enlarge the magnitude of the compensating plate **116** such that the magnitude can receive all of a plurality of dispersed lights, as is different from the case that the light path compensating portion is arranged in the light path between the dispersing portion **112** and the deflecting portion **115**, and shifts the light dispersed by the compensating plate **116**. Making the magnitude of the compensating plate **116** comparatively small can contributes a downsizing of the wavelength selecting switch **100** and the optical unit **102** for the wavelength selecting switch according to the present embodiment.

Further, in the wavelength selecting switch **100** according to the present embodiment, since the light path compensating portion is provided with the compensating plate **116** which is the optical element for compensating the light path, and the actuator **117**, and the actuator **117** is controlled by the electric signal from the adjusting portion **121** which is provided in the external portion of the casing **118**, it is possible to drive the light path compensating portion while maintaining a sealing performance in the casing **118**.

In the optical system in the casing, the first converging element **113***a* may be constructed by two cylindrical lenses which are different in diameter for forming an input light. For example, two cylindrical lenses are formed as an oval shape in a cross section of the light entering from the input port. Alternatively, the shape of the lens for forming the input light may be formed every shapes which can form the cross section of the light as an oval shape, without being limited to the cylindrical lens.

Second Embodiment

FIG. **3**A is a plan view showing an outline structure of a wavelength selecting switch **200** according to a second embodiment of the present invention. FIG. **3**B is a side elevational view showing the outline structure of the wavelength selecting switch **200** according to the present embodiment.

The wavelength selecting switch **200** according to the present embodiment is provided with an optical unit **201** for a wavelength selecting switch, the optical unit **201** being provided with a casing **218** which hermetically embeds an optical fiber array **209**, an input and output port **210**, a lens array **211**, a first converging element **213***a*, a second converging element **213***b*, a dispersing element **212***a*, a reflection element **212***b*, a reflection element moving member **212***c*, a mirror portion **213** and an actuator **217** and has a window **219**, and an adjusting portion **221**, and the wavelength selecting switch **200** is also provided with a deflecting portion casing **220** which embeds a deflecting portion **215**. Reference numerals obtained by adding 100 to the reference numerals in the first embodiment are attached to the same or corresponding constructing elements to those of the first embodiment, and a description thereof will be omitted.

Two converging elements **113***b* and **113***c* which are provided one by one in the front and rear sides of the dispersing portion **112** in the first embodiment, however, are in common to a converging element **213***b*. Further, the dispersing portion **112** is described in the first embodiment, however, in the present embodiment, a dispersing portion **212** is constructed by the dispersing element **212***a*, the reflection element **212***b* and the reflection element moving member **212***c*. Further, both of a light path between the input and output port **210** and the dispersing portion **212**, and a light path between the dispersing portion **212** and the deflecting portion **215** pass through the converging element **213***b*.

In the wavelength selecting switch **200** according to the present embodiment, the dispersing element **212***a* of a transmission type and the reflection element **212***b*, which construct the dispersing portion **212** are arranged so as to form a Littman-Metcalf configuration. The reflection element **212***b* is attached to the reflection element moving member **212***c*. The actuator **217** is provided so as to come into contact with the reflection element moving member **212***c*. The actuator **217** is constructed, for example, by PZT, and expands and contracts in correspondence to applied voltage. Although an illustration is omitted, an elastic body is provided in an opposite side to the actuator **217** in relation to the reflection element moving member **212***c*. Further, a stopper (not shown) is arranged so as to come into contact with the elastic body.

The adjusting portion **221** of the wavelength selecting switch **200** and the optical unit **201** for the wavelength selecting switch according to the present embodiment controls the voltage applied to the actuator **217**. In correspondence to the voltage applied by the adjusting portion **221**, the actuator **217** is driven so as to rotate the reflection element moving member **212***c* around a rotary shaft (not shown). Further, a light flux entering into the deflecting portion **215** is shifted by the rotation of the reflection element moving member **212***c*. In other words, in the present embodiment, the reflection element **212***b*, the reflection element moving member **212***c* and the actuator **217** serve as a light path compensating portion.

A description will be given of a principle that the light flux entering into the deflecting portion **215** is shifted by the rotation of the reflection element moving member **212***c* with reference to FIG. **3**C. Since the light path from the input and output port **210** to the dispersing portion **212** is approximately the same as the first embodiment, the light path will be omitted. FIG. **3**C only shows a light flux of particular one wavelength heading to the deflecting portion **215** from the reflection element **212***b*. After the light flux having the particular wavelength enters as the parallel light flux to the reflection element **212***b*, the incident light flux is reflected. The reflected light flux is deflected in a direction which is angularly different from the light flux coming from the input and output port **210** by the dispersing element **212***a*. The deflected light flux enters into the second converging element **213***b*, and is converged to one of deflecting elements constructing the deflecting portion **215** by the second converging element **213***b*. On the basis of the rotation of the reflection element moving member **212***c*, the reflection element **212***b* fixed to the reflection element moving member **212***c* rotates, and an incident angle of the light flux entering into the second converging element **213***b* changes. If the incident angle of the light flux entering into the second converging element **213***b* changes, a converging position of the light flux on the deflecting elements constructing the deflecting portion **215** changes. In other words, a shift amount of the converging position by the second converging element **213***b* is product of an angular change amount of the light flux entering into the second converging element **213***b* and a focal distance of the second converging element **213***b*. The angular change amount of the light flux entering into the second converging element **213***b* is twice the rotating angle of the reflection element moving member **212***c*. Accordingly, the converging point converged on the deflecting element of the deflecting portion **215** by the second converging element **213***b* is shifted by an amount which is in proportion to the rotating angle of the reflection element moving member **212***c*.

The wavelength selecting switch **200** according to the present embodiment is provided with the dispersing element **212***a* and the reflection element **212***b* which are arranged so as to form the Littman-Metcalf configuration, and the adjusting portion **221** provided in the external portion of the casing **218** of the wavelength selecting switch **200** shifts the incident position of the light relation to the deflecting portion **215** by displacing the reflection element **212***b*. Accordingly, the wavelength selecting switch **200** according to the present embodiment can drive the light path compensating portion from the external portion of the casing **218** while maintaining the sealing performance. Further, since it is not necessary to add any optical element for compensating the light path to the optical system in the casing **218**, it is possible to apply the light flux adjusting function while suppressing an increase of the number of the parts constructing the wavelength selecting switch **200**.

Third Embodiment

FIG. **4**A is a plan view showing an outline structure of a wavelength selecting switch **300** according to a third embodiment of the present invention. FIG. **4**B is a side elevational view describing the outline structure of the wavelength selecting switch **300** according to the present embodiment. The wavelength selecting switch **300** according to the present embodiment is provided with an optical unit **301** for a wavelength selecting switch, the optical unit **301** being provided with a casing **318** which hermetically embeds an optical fiber array **309**, an input and output port **310**, a lens array **311**, a first converging element **313***a*, a first mirror portion **314***a*, a second converging element **313***b*, a temperature compensating prism **326**, a Grism **312**, a second mirror portion **314***b*, a third converting element **313***c*, a compensating plate **316**, a rotary shaft **323** and a third mirror portion **314***c* and has a window **319**, and an adjusting portion **221** which is constructed by a retaining portion **327** retaining a magnet (not shown), and the wavelength selecting switch **300** is also provided with a deflecting portion casing **320** which embeds a deflecting portion **315**. Reference numerals obtained by adding 200 to the reference numerals in the first embodiment are attached to the constructing elements having the same functions as those of the first embodiment, and a description thereof will be omitted.

The temperature compensating prism **326** is a prism which deflects an input light so as to output to the Grism **312**. The temperature compensating prism **326** may be set its shape, arrangement, medium and other conditions in such a manner that an incident angle of the light from the deflecting portion **315** to the output port becomes approximately fixed in relation to a temperature change in a used temperature range of the wavelength selecting switch **300** according to the present embodiment. The Grism **312** is one of the dispersing elements obtained by combining the prism and the diffraction grating. A light path compensating portion according to the present embodiment is provided with a compensating plate **316** which constructs an optical element for compensating the light path, and a magnetic body **330**.

Next, a description will be given of an outline structure of the light path compensating portion of the wavelength selecting switch **300** according to the present embodiment with reference to FIGS. **5**A and **5**B. FIG. **5**A is a view for describing the outline structure of the light path compensating portion. FIG. **5**A is a view of the light path compensating portion as seen from a direction a in FIG. **4**A. In the same manner as the first embodiment, the compensating plate **316** is supported by a support body **322**, and is constructed, for example, by parallel flat plates. The support body **322** can rotate about a rotary shaft **323** which is fixed to the casing **318**. Here, in the present embodiment, the magnetic body **330** is provided in an end portion in an opposite side to the rotary shaft **323** in relation to the support body **322**.

Further, in the vicinity of an upper portion of the magnetic body **330**, a nonmagnetic material portion **329** is provided in the casing **318**. Further, a magnet **328** constructing an adjusting portion which adjusts a shift amount of an incident position of the light in relation to the deflecting portion **315** by the light path compensating portion (the compensating plate **316** and the magnetic body **330**) is arranged in a concave portion which is provided in the nonmagnetic material portion **329**. The magnet **328** is retained by the retaining portion **327**.

FIG. **5**B is a view for describing an outline structure of the light path compensating portion, and is a view of the light path compensating portion as seen from a direction b in FIG. **4**A. An elastic member **331** is attached to one side surface of the magnet **328**. The other end of the elastic member **331** is attached to the retaining portion **327**. The magnet **328** moves in a direction of an illustrated arrow X by rotating a micrometer **332**. In correspondence to the movement of the magnet **328**, the compensating plate **316** rotates about the rotary shaft **323**. On the basis of the rotation of the compensating plate **316**, the light flux entering into the deflecting portion **315** is shifted.

Here, with reference to FIG. **5**C, a description will be given of the shift of the light flux entering into the deflecting portion **315** by the rotation of the compensating plate **316**. Since the light path from the input and output port **319** to the third converging element **313***c* is approximately the same as the first embodiment, the light path will be omitted. In FIG. **5**C, the light flux entering into the deflecting portion **315** is shown only by the light flux of one particular wavelength. The parallel light fluxes enter into the third converging element **313***c*, and are converged on one deflecting element of the deflecting portion **315**. When the compensating plate **316** existing between the third converging element **313***c* and the deflecting portion **315** rotates, the converging position is shifted as is apparent from the drawing. A shift amount dx can be approximated by the following expression.

$$dx=t\theta/n$$

where n is refraction factor of the compensating plate **316**, t is thickness thereof and θ is rotating angle.

The shift amount is in proportion to the rotating angle of the compensating plate **316**. Accordingly, the light flux entering into the deflecting portion **315** by the rotation of the compensating plate **316** is shifted.

As mentioned above, in the wavelength selecting switch **300** and the optical unit **301** for the wavelength selecting switch according to the present embodiment, the incident position of the light in relation to the deflecting portion **315** is shifted by moving the magnet **328** constructing the adjusting portion. As mentioned above, according to the wavelength selecting switch **300** and the optical unit **301** for the wavelength selecting switch according to the present embodiment, it is possible to drive the light path compensating portion while maintaining a sealing performance in the casing **318**. Further, in the wavelength selecting switch **300** according to the present embodiment, since the compensating portion **316** is rotated by the magnet **328**, it is possible to reduce an electric power consumption.

In the wavelength selecting switch **300** and the optical unit **301** for the wavelength selecting switch according to the present embodiment, the compensating plate **316** is structured, for example, such that the compensating plate **316** is constructed by the parallel flat plates and is shifted by the magnet **328**, however, the compensating plate **316** may be constructed by an electro-optic device (hereinafter, refer to as EOD). EOD is a device which is changed its refraction factor in correspondence to the applied voltage. In other words, EOD has a function of shifting the light path only at an amount corresponding to the applied voltage. In the case that the compensating plate **316** is constructed by the EOD, the compensating plate **316** is provided in an inclined manner. Further, in this case, the rotary shaft **323** is not necessary. As a representative EOD, KTN (potassium tantalate niobate), PZT (registered trademark) (lead zirconate titanate), lithium niobate ($LiNbO_3$), and KTP ($KTiOPO_4$) can be listed up.

In the case that the compensating plate **316** is constructed by EOD, the compensating plate **316** is connected to the adjusting portion which is provided in an outer portion of the casing **318**, for example, by a conducting wire. At this time, the adjusting portion controls the voltage applied to the compensating plate **316** so as to change the refraction factor of the compensating plate **316**, and changes the light path of the light passing through the compensating plate **316**. Accordingly, the adjusting portion adjusts the shift amount of the incident position in relation to the deflecting portion **315**. As mentioned above, the wavelength selecting switch **300** and the optical unit **301** for the wavelength selecting switch according to the present embodiment can adjust the light path compensating portion (the compensating plate **316**) in the casing while maintaining the sealing performance.

In the present embodiment, the description is given on the assumption that the light path compensating portion has the magnetic body **330** and the adjusting portion has the magnet **328** respectively, however, the concept of the present invention exists in cooperation of the light path compensating portion and the adjusting portion by a magnetic force. Accordingly, the wavelength selecting switch according to the present embodiment may be structured such that the light path compensating portion has the magnet, and the adjusting portion has the magnetic body respectively. Further, in the present embodiment, the temperature adjusting prism **326** is arranged, however, the temperature adjusting prism is not necessarily arranged. Further, the various dispersing portions **112** exemplified in the first embodiment may be employed in place of the Grism **312**.

Fourth Embodiment

FIG. **6** is a plan view showing an outline structure of a wavelength selecting switch **400** according to a fourth embodiment of the present invention. Since a structure in a casing **418** is approximately the same as the first embodiment except a structure that the actuator is not provided, reference numerals obtained by adding 300 to the reference numerals in the first embodiment are attached to the same or corresponding constructing elements to the constructing elements of the first to third embodiments, and a description thereof will be omitted. Here, a description will be given only of different constructing elements from the first embodiment. Although not being illustrated, a wavelength selecting switch **400** according to the present embodiment is provided with an optical unit for a wavelength selecting switch, the optical unit being provided with a casing **418** which hermetically embeds various optical elements in common with the first embodiment and has a window (not shown), and an adjusting portion (not shown), and a deflecting portion casing (not shown) which embeds a deflecting portion.

FIGS. **7**A and **7**B are views for describing an outline structure of a light path compensating portion according to the fourth embodiment. FIG. **7**A is a plan view of a support body **422** according to the present embodiment. FIG. **7**B is a view of the light path compensating portion as seen from a direction a in FIG. **6**. The support body **422** is provided with a magnetic body **430** in an upper surface (a surface in an opposite side to a surface supporting the compensating plate **416**), and has a pressure sensitive adhesive sealing portion **441**. An ultraviolet light curable pressure sensitive adhesive **442** is sealed in the pressure sensitive adhesive sealing portion **441**.

FIG. **7**C is a view of the light path compensating portion as seen from a direction b in FIG. **6**. The casing **418** is provided with a transparent window **443** on the pressure sensitive adhesive sealing portion **441**, and is provided with a magnet **428** on the magnetic body **430**. The magnet **428** is retained by a retaining portion **427**. An adjusting mechanism of the light path adjusting portion by the magnet **428** conforms to the same mechanism of the magnet **328** and the retaining portion **327** according to the third embodiment shown in FIGS. **5**A and **5**B.

A description will be given below of a fixing method of the wavelength selecting switch **400** and the light path compensating portion of the optical unit for the wavelength selecting switch according to the present embodiment. First of all, as mentioned above, the compensating plate **416** constructing the light path compensating portion is inclined at a desired angle by the magnet **428** constructing the adjusting portion. Further, the ultraviolet light curable pressure sensitive adhesive **442** sealed in the pressure sensitive adhesive sealing portion **441** is cured by irradiating the ultraviolet light via the transparent window **443**. As mentioned above, in the wavelength selecting switch **400** and the optical unit for the wavelength selecting switch according to the present embodiment, it is possible to adjust the light path compensating portion within the casing **418** while maintaining a sealing performance of the casing **418**, and it is possible to fix the light path compensating portion to the casing **418** in the adjusted state.

Further, in the present embodiment, the compensating plate **416** can be fixed at a desired inclined angle by replacing the pressure sensitive adhesive sealed in the pressure sensitive adhesive sealing portion **441** by a thermosetting type pressure sensitive adhesive, replacing the transparent window **443** by a high heat conducting member, making the compensating plate **416** incline at a desired angle and thereafter curing the thermosetting type pressure sensitive adhesive by heat.

FIG. **8**A is a view showing a modified example of the wavelength selecting switch according to the fourth embodiment of the present invention. The pressure sensitive adhesive sealed in the pressure sensitive adhesive sealing portion **441** is constituted by a two-liquid curing type pressure sensitive adhesive. The two-liquid curing type pressure sensitive adhesive is constructed by a first liquid **442***a* and a second liquid **442***b*. The first liquid **442***a* is sealed in the pressure sensitive adhesive sealing portion **441**. The second liquid **442***b* has a micro magnetic bead **445** and exists in a state in which the second liquid **442***b* is adsorbed around the magnetic bead **445**, as shown in FIG. **8**B. Further, the magnetic bead **445** to which the second liquid **442***b* is attached is attracted by a magnet **444** for the pressure sensitive adhesive from an external portion of the casing **418**, and is fixed to an inner wall of the casing **418**, such as the second liquid **442***b* shown in FIG. **8**A. Further, after the compensating plate **416** is inclined at a desired angle by actuating the light path compensating portion by the magnet **428**, the magnet **444** for the pressure sensitive adhesive is detached from the casing **418**. Then, the magnetic bead **445** attracted by the magnet **444** for the pressure sensitive adhesive drops into the first liquid **442***a*, and the first liquid **442***a* and the second liquid **442***b* are mixed so as to be cured.

According to the present modified example, after adjusting the optical system in the casing **418** by the method as mentioned above, it is possible to fix the light path compensating portion having the adjusted light flux while maintaining the sealing performance, by utilizing the magnetic bead and the two-liquid curing type pressure sensitive adhesive.

As mentioned above, in the wavelength selecting switch **400** and the optical unit for the wavelength selecting switch according to the present embodiment, since the light path compensating portion is fixed by the pressure sensitive adhesive, the deflecting casing cannot replaced due to the failure of the deflecting portion **415**, however, it is possible to adjust the optical system embedded in the casing **418** in conformity to the deflecting portion **415** in relation to a fine movement at the curing time of the pressure sensitive adhesive when the deflecting portion casing (not shown) is attached later. Since the light path compensating portion is fixed by the pressure sensitive adhesive, the magnet **428** outside the casing **418** can be detached after being adjusted. Further, any power for retaining the light path compensating portion is not necessary. Further, since the light path compensating portion is firmly fixed by the pressure sensitive adhesive, it is possible to suppress the movement of the light path compensating portion in relation to a shock from an external portion.

In the same manner as the third embodiment, in the present embodiment, the description is given on the assumption that the light path compensating portion has the magnetic body **430**, and the adjusting portion has the magnet **428** respectively. However, the concept of the present invention exists in cooperation of the light path compensating portion and the adjusting portion by the magnetic force. Accordingly, the wavelength selecting switch according to the present embodiment may be structured such that the light path compensating portion has the magnet, and the adjusting portion has the magnetic body respectively.

Fifth Embodiment

FIGS. **10**A and **10**B are views schematically showing a structure of a substantial part of a wavelength selecting switch according to a fifth embodiment of the present invention. FIG. **10**A is a view of the wavelength selecting switch as seen from a wavelength dispersing direction by a dispersing portion, and FIG. **10**B is a view of the wavelength selecting switch as seen from a direction which is orthogonal to the wavelength dispersing direction by the dispersing portion. In the following description, as a matter of convenience, FIG. **10**A is assumed to be a front face side and FIG. **10**B is assumed to be a plane side.

The wavelength selecting switch is provided with one input port **510***a*, four output ports **510***b* to **510***e*, a micro lens array **520**, a dispersing portion **530**, a converging lens **540** serving as a converging element, a deflecting portion **550** and a casing **560**. In FIGS. **10**A and **10**B, for showing an internal structure of the casing **560**, a front face plate **560***a* of the casing **560** is removed in FIG. **10**A, and a top face plate **560***b* of the casing **560** is removed in FIG. **10**B. Further, in FIGS. **10**A and **10**B, a wavelength dispersing direction by the dispersing portion **530** is set to an X direction, a vertical direction to a surface on which a dispersed light spatially expands on the basis of a wavelength dispersion of the dispersing portion **530** is set to a Y direction, and a direction which is orthogonal to the X direction and the Y direction is set to a Z direction. In the case that a deflecting portion material such as a mirror or a prism which is not illustrated is arranged in the light path of the actual wavelength selecting switch for folding the light path, the description of the X direction, the Y direction and the Z direction is used on the assumption of a virtual optical system having no deflecting portion material.

The input port **510***a* and the output ports **510***b* to **510***e* are arranged linearly in the Y direction. Hereinafter, for convenience of explanation, the input port **510***a* and the output ports **510***b* to **510***e* are collectively described as input and output ports **510** appropriately. An end portion of an optical fiber is retained to each of the input and output ports **510**. The optical fiber is omitted its illustration for clarifying the drawings. The micro lens array **520** is provided with spherical or aspherical micro lenses **521***a* to **521***e* corresponding to the input ports **510**.

A light signal (an input light) which is emitted from the input port **510***a* and is wavelength divided and multiplexed is converted into parallel lights by the corresponding micro lens **521***a* of the micro lens array **520**, and is incident to the dispersing portion **530**.

The dispersing portion **530** has a dispersing element **531**, for example, constructed by a transmission type grating, and disperses the input light from the input port **510***a* to the light signal per wavelength. FIG. **10**B exemplifies a case that the dispersing portion **530** can disperse the input light into the light signal per five wavelengths. In the present embodiment, only five wavelengths are exemplified as the dispersed wavelength, however, the number of the wavelengths is not limited to this number.

The converging lens **540** is arranged so that a front focal point position approximately coincides with a dispersing base point of the dispersing element **531**, and converges the light signal which is wavelength dispersed by the dispersing portion **530** into the deflecting portion **550**. Here, in the case that the input light is wavelength divided and multiplexed by a plurality of discrete wavelengths, the wavelength dispersed light signal is separated per wavelength and converged into the deflecting portion **550**. Further, a plurality of light signals converged by the converging lens **540** preferably enter into the deflecting portion **550** approximately vertically as seen from a vertical direction to the wavelength dispersing direction.

The deflecting portion **550** is provided with a plurality of deflecting elements which are arranged linearly in the wavelength dispersing direction of the dispersing portion **530**. In the present embodiment, the deflecting portion **550** is exemplified by the case that the deflecting portion is provided with five deflecting elements **551***a* to **551***e*, however, the number of the deflecting elements is not limited to this number. The deflecting elements **551***a* to **551***e* correspond to five wavelengths which are dispersed by the dispersing portion **530**, and are structured such that the deflecting elements can be independently driven from each other. Accordingly, each of the light signals per wavelength entering into the deflecting portion **550** is deflected. The deflecting portion **550** which is provided with the array-like deflecting elements **551***a* to **551***e* is constructed, for example, by using a MEMS (micro electro mechanical systems) mirror, a liquid crystal device and an optical crystal.

The light signal per wavelength which is deflected by the deflecting portion **550** is incident as an output light to each of the desired output ports **510***b* to **510***e* via the converging lens **540** and the dispersing portion **530**. FIG. **10**A exemplifies a case that the output light is incident to the output port **510***c*.

The casing **560** has the front face plate **560***a*, the top face plate **560***b*, left and right side face plates **560***c* and **560***d*, a back face plate **560***e* and a bottom face plate **560***f*, and an area (a project area) of the top face plate **560***b* and the bottom face plate **560***f* is larger than an area (a project area) of the front face plate **560***a*, the left and right side face plates **560***c* and **560***d* and the back face plate **560***e*. Name of each of the faces of the casing **560** is put in the case that FIG. **10**A is a front face side as a matter of convenience. Further, FIG. **10**A is a view showing while removing the front face plate **560***a*, and FIG. **10**B is a view showing while removing the top face plate **560***b*. In the wavelength selecting switch according to the present embodiment, an optical base plate **570** serving as an optical bench is attached to the back face plate **560***e* of the casing **560**, the input and output port **510**, the dispersing portion **530**, the converting lens **540** and the deflecting portion **550** being supported to the optical base plate **570**.

The optical base plate **570** is formed by a material having a comparatively small linear expansion coefficient, for example, metal or glass, and is attached to a plurality of (two in the drawing) support tables **561** provided in the back face plate **560***e* by screws **562**. In other words, the optical base plate **570** is attached to the back face plate **560***e* in such a manner that support surfaces **570***a*, **570***b* and **570***c* mentioned later intersect, preferably are orthogonal in relation to the top face plate **560***b* and the back face plate **560***f* having the largest project area. In the present embodiment, in order to easily fasten the optical base plate **570** to the back face plate **560***e* of the casing **560**, the screws **562** are used, however, the fastening may be achieved by using a pressure sensitive adhesive without being limited to the screws **562**. Further, the number of the screws **562** is not limited.

Here, the input and output port **510** is fixed to an input and output unit substrate **512** via a port support substrate **511** by adhesive bonding. Further, the micro lens array **520** is fixed to the input and output unit substrate **512** by adhesive bonding in such a manner that the micro lenses **521***a* to **521***e* correspond to the respective ports **510***a* to **510***e* of the input and output port **510**. Further, the input and output unit substrate **512** to which the input and output port **510** and the micro lens array **520** are fixed is supported to the support surface **570***a* of the optical base plate **570** by adhesive bonding. In other words, the input and output port **510** and the micro lens array **520** are unitized so as to be supported by the optical base plate **570**. In the present embodiment, taking assembly easiness into consideration, the input and output port **510** and the micro lens array **520** are unitized by using the port support substrate **511** and the unit substrate **512** and are supported by the optical base plate, however, may be structured such that the input and output port **510** and the micro lens array **520** are directly supported by the optical base plate without being unitized and without using the port support substrate **511** and the unit substrate **512**.

Further, the dispersing element **531** constructing the dispersing portion **530** is supported by the support surface **570***b* of the optical base plate **570**. The dispersing element **531** is fixed to the support surface **570***b* of the optical base plate **570** by adhesive bonding. Each of the converging lens **540** and the deflecting portion **550** is fixed to the support surface **570***c* of the optical base plate **570** by adhesive bonding. A flexible substrate **552** connected to the deflecting portion **550** is derived to an external portion through an extraction port **560***g* formed in the bottom face plate **560***f*. In order to keep a sealing performance in an internal portion of the casing **560**, a gap between the extraction port **560***g* and the flexible substrate **552** is filled by a sealant **563**.

The optical base plate **570** can be constructed by being separated into a plurality of members as shown in FIGS. **11**A and **11**B. At this time, a plurality of members can be coupled by various coupling methods, for example, can be coupled by a pressure sensitive adhesive as shown in FIG. **11**A, or can be coupled by screws **565** as shown in FIG. **11**B.

As shown in FIG. **10**B, the optical base plate **570** is formed as a folded shape that the support surface **570***a* of the input and output unit substrate **512** is inclined in relation to the support surface **570***c* of the dispersing portion **530**, the converting lens **540** and the deflecting portion **550** in such a manner that the optical axis of the converging lens **540** and the support surface **570***c* are approximately parallel. Accordingly, the back face plate **560***e* of the casing **560** is folded in conformity to the folded shape of the optical base plate **570**. However, the back face plate **560***e* can be formed as a rectangular box shape as a whole of the casing **560**, by elongating the support table **561** so as to form a flat shape which is parallel to the front face plate **560***a*. FIG. **10**A shows so that the input light from the input port **510***a* enters into the dispersing portion **530**, the output light from the dispersing portion **530** vertically emits, and the input and output port **510**, the micro lens array **520**, the dispersing portion **530**, the converging lens **540** and the deflecting portion **550** are arranged linearly in the Z direction, for clarifying the drawing.

As mentioned above, in the present embodiment, the optical base plate **570** is attached to the back face plate **560***e* in such a manner that the support surfaces **570***a*, **570***b* and **570***c* intersect the top face plate **560***b* and the bottom face plate **560***f* having the largest project area. Accordingly, since it is possible to easily secure a necessary thickness of the optical base plate **570** without enlarging a height (thickness) of the casing **560**, it is possible to easily thin the casing **560**.

One input port **510***a* and four output ports **510***b* to **510***e* are exemplified in FIG. **10**A, however, there is a case that the input port **510***a* comes to the output port, and the output ports **510***b* to **510***e* come to the input ports. Further, the numbers of the input port and the output port are not limited to the exemplification, but can be appropriately set. In other words, the wavelength selecting switch according to the present invention is not limited to the case that the input light which is wavelength divided and multiplexed is dispersed per wavelength so as to be output as mentioned above, but includes a case that the wavelength selecting switch is used so as to multiply a plurality of input lights per wavelength so as to output. Further, the input port and the output port are not limited to the case that the input port and the output port are arranged as an array at one position, but include a case that the input port and the output port are spatially separated so as to be arranged at different positions.

Sixth Embodiment

FIGS. **12**A and **12**B are views schematically showing a structure of a substantial part of a wavelength selecting switch according to a sixth embodiment of the present invention. FIGS. **12**A and **12**B correspond to FIGS. **10**A and **10**B, and the same reference numerals are attached to the constructing elements having the same actions as the constructing elements shown in FIGS. **10**A and **10**B and a description thereof will be omitted.

The wavelength selecting switch according to the present embodiment is structured such that a folding mirror **580** is arranged in a light path between the converging lens **540** and the deflecting portion **550** in the structure shown in FIGS. **10**A and **10**B, thereby folding the light path approximately at 90 degrees to the bottom face plate **560***f* side. The folding mirror **580** is firmly attached to the support surface **570***c* of the optical base plate **570** by adhesive bonding. Further, the deflecting portion **550** is firmly attached to the support surface **570***c* of the optical base plate **570** by adhesive bonding in a posture that the deflecting portion is rotated approximately at 90 degrees in relation to a posture of the fifth embodiment, in such a manner that the dispersed light which is reflected by the folding mirror **580** enters into the deflecting elements **551***a* to **551***e*. In other words, the deflecting portion **550** is supported to the optical base plate **570** in such a manner that the arranging direction of the deflecting elements **551***a* to **551***e* is approximately parallel to the bottom face plate **560***f*. Further, the flexible substrate **552** of the deflecting portion **550** is derived to the external portion through the extraction port **560***h* formed in the side face plate **560***d*. In order to keep the sealing performance in the internal portion of the casing **560**, a gap between the extraction port **560***h* and the flexible substrate **552** is filled by the sealant **563**.

As mentioned above, in the present embodiment, the deflecting portion **550** is supported by the optical base plate **570** in such a manner that the arranging direction of the deflecting elements **551***a* to **551***e* of the deflecting portion **550** becomes approximately parallel to the bottom face plate **560***f*, in the structure according to the fifth embodiment. Accordingly, since a magnitude of the deflecting portion **550** is not limited in the arranging direction (X direction) of the deflecting elements **551***a* to **551***e* and the Z direction which is orthogonal thereto, it is possible to easily cope with the increase of the wavelength dividing number, that is, the port number, in addition to the effects of the fifth embodiment.

Seventh Embodiment

FIGS. **13**A and **13**B are views schematically showing a structure of a substantial part of a wavelength selecting switch according to a seventh embodiment of the present invention. FIGS. **13**A and **13**B correspond to FIGS. **10**A and **10**B, however, FIG. **13**A shows by expanding an optical system in FIG. **13**B. In the following description, the same reference numerals are attached to the constructing elements having the same actions as the constructing elements shown in FIGS. **10**A and **10**B and a detailed description thereof will be omitted.

In the wavelength selecting switch according to the present embodiment, a light signal (an input light) which is emitted from the input port **510***a* and is wavelength divided and multiplexed is converted into parallel lights by the corresponding micro lens **521***a*, and is thereafter incident to the converging lens **540** via a converging point F by a primary converging lens **541**.

The converging lens **540** is arranged in such a manner that a front focal point position thereof is positioned in the vicinity of the converging point F of the input light by the primary converging lens **541**, and makes the input light from the input port **510***a* entering via the converging point F enter into the dispersing portion **530**.

The dispersing portion **530** is provided with a dispersing element **531** which is constructed by a transmission type grating, and a folded mirror **533** which is a reflection element, and has a Littman-Metcalf configuration which reflects the dispersed light by the dispersing element **531** by the folding mirror **533** and again makes the dispersed light enter into the dispersing element **531**. The dispersing element **531** is arranged in such a manner that a dispersing base point is positioned in the vicinity of a rear focal point position of the converging lens **540**.

The light which is wavelength dispersed by the dispersing portion **530** so as to be emitted is converged by the converging lens **540**, is deflected approximately at 90 degrees by a reflection prism **581**, and is entered into the deflecting elements **551***a* to **551***e* which correspond to the wavelength of the deflecting portion **550**. Further, the light is independently deflected by the deflecting elements **551***a* to **551***e*, and is entered as an output light into the desired output ports **510***b* to **510***e* via the reflection prism **581**, the converging lens **540**, the dispersing portion **530**, the converging lens **540** and the primary converging lens **541**. FIG. **13**A exemplifies a case that one of the dispersed lights by the dispersing portion **530** is entered into the output port **510***c*, and FIG. **13**B exemplifies a case that one light is dispersed into three wavelengths by the dispersing portion **530**.

In the structure mentioned above, the input and output port **510** and the micro lens array **520** are unitized into the input and output unit substrate **512** in the same manner as the fifth embodiment, and are supported to one end portion of the support surface **570***d* of the optical base plate **570**. The primary converging lens **541** and the converging lens **540** are fixed to the support surface **570***d* of the optical base plate **570** by adhesive bonding in such a manner that each of optical axes is approximately parallel to the support surface **570***d*.

The dispersing element **531** constructing the dispersing portion **530** is supported to a support surface **570***e* in a leading end portion which extends approximately vertically from the support surface **570***c* in the other end portion of the support surface **570***d* of the optical base plate **570**. Further, the folded mirror **533** is supported to the support surface **570***d* of the optical base plate **570**. The dispersing element **531** is fixed to the support surface **570***d* of the optical base plate **570** by adhesive bonding. In the same manner, the folded mirror **533** is fixed to the support surface **570***d* by adhesive bonding.

Each of the reflection prism **581** and the deflecting portion **550** is fixed to a support surface **571***a* of a support portion **571** which is formed by protruding approximately vertically from the support surface **570***d* of the optical base plate **570** by adhesive bonding between the primary converging lens **541** and the converging lens **540**, and is supported to the optical base plate **570**. The support portion **571** is formed in the optical base plate **570** in such a manner as to cut across the primary converging point by the primary converging lens **541** or the light path in the vicinity thereof, and an opening portion **571***b* serving as a light transmitting portion is formed in a portion through which the input light and the output light in relation to the input and output port **510** pass.

Further, the optical base plate **570** is attached to the support table **561** provided in the back face plate **560***e* by screws **562** in such a manner that the support surfaces **570***d*, **570***e* and **571***a* intersect, preferably are orthogonal, in relation to the top face plate **560***b* and the bottom face plate **560***f* having the largest project area, in the same manner as the fifth embodiment. FIG. **13**A shows the optical element on which the input light and the output light act, by expanding linearly in the Z direction, between the input and output port **510** and the reflection prism **581**.

According to the present embodiment, since the optical base plate **570** is attached to the back face plate **560***e*, it is possible to easily secure a necessary thickness of the optical base plate **570** without enlarging the height (thickness) of the casing **560** in the same manner as the above embodiment. Accordingly, it is possible to easily thin the casing **560**.

Further, in the present embodiment, the input light from the input port **510***a* is wavelength dispersed by the dispersing portion **530** having the Littman-Metcalf configuration via the primary converging lens **541** and the converging lens **540**, and is thereafter deflected by the deflecting portion **550** via the reflection prism **581**. Further, the deflected light is output from the output port **510***c* via the reflection prism **581**, the dispersing portion **530**, the converging lens **540** and the primary converging lens **541**. Further, since the support portion **571** supporting the reflection prism **581** and the deflecting portion **550** is arranged at the primary converging point by the primary converging lens **541** or the position which cuts across the light path in the vicinity thereof, it is possible to make the opening portion **571***b* transmitting the input light and the output light small. As a result, it is possible to make the support portion **571** itself small. Therefore, it is possible to enlarge a spatial expanding width of the dispersing light in the disperse light path while being formed as a compact structure as a whole, and it is possible to achieve an improvement of S/N of the output light and a reduction of a cross talk.

Further, since the deflecting portion **550** is supported by the support portion **571** in such a manner that the arranging direction of the deflecting elements **551***a* to **551***e* is approximately parallel to the bottom face plate **560***f*, it is possible to easily cope with the increase of the wavelength dividing number, that is, the increase of the port number, in the same manner as the sixth embodiment.

In the wavelength selecting switch according to the seventh embodiment, as shown in FIG. **14**, the light paths of the input light and the output light can be set to be spaced from a support post **572** by forming the block-shaped support post **572** in one end portion of the optical base plate **570**, attaching the input and output unit substrate **512** obtained by unitizing the input and output port **510** and the micro lens array **520** to a front face side support surface **572***a* of the support post **572**, and attaching the reflection prism **581** and the deflecting portion **550** (not shown) or only the deflecting portion **550** to a side face side support surface **572***b*.

Eighth Embodiment

Before describing in detail an eighth embodiment, a description will be given of basic structure and action of the wavelength selecting switch with reference to a side elevational view in FIG. **15**A and a top elevational view in FIG. **15**B.

A wavelength selecting switch **601** is structured such as to include an input and output portion **610**, a micro lens array **611**, cylindrical lens **612** and **613**, a lens **614**, a dispersing portion **615**, a lens **616** constructing a converging portion, and a deflector **617** constructing a deflecting portion.

In FIGS. **15**A and **15**B, the input and output portion **610** is provided with an input port **610***a* and output ports **610***b* to **610***e* which are constructed by optical fibers arranged like an array. The input port **610***a* and the output ports **610***b* to **610***e* are structured respectively such as to input a wavelength multiplexed signal light from an external portion of the wavelength selecting switch **601** and output the signal light to the external portion. Hereinafter, for convenience of explanation, the input port **610***a* and the output ports **610***b* to **610***e* are collectively described the input and output ports **610***a* to **610***e* appropriately. One end portion of each of the optical fiber exists in the wavelength selecting switch **601**, and the other end thereof is connected to the external portion of the wavelength selecting switch **601**. The number of the input and output ports is set, for example, equal to or more than 10, and the number of the output ports can be set to be more than the number of the input ports. However, in FIG. **15**A, for convenience of explanation, only five input and output ports **610***a* to **610***e* arranged in series centering on the input and output port **610***c* are illustrated.

Further, each of the input and output ports **610***a* to **610***e* and each of the micro lenses in the micro lens array **611** form a pair. Each of the micro lenses converts the light input from the input port **610***a* into parallel light fluxes, and couples the parallel light fluxes output toward the output ports **610***b* to **610***e* to the optical fiber. Further, the light which is input into the wavelength selecting switch **601** through the input port **610***a* and the micro lens of the micro lens array **611**, and the light which is output toward the corresponding micro lens to the output ports **610***b* to **610***e* form the parallel light fluxes.

In the following description, a forward moving direction of the parallel lights passing through the input and output port **610***a* and the corresponding micro lens of the micro lens array **611** is set to an optical axis direction (z direction). The optical axis direction is also an optical axis direction of an optical system which is constructed by a combined lens constituted by the cylindrical lenses **612** and **613** and the lens **614**. Further, a direction in which the input and output ports **610***a* to **610***e* and the micro lens array **611** are arranged is set to a first direction (y direction). The optical axis direction and the first direction (y direction) are orthogonal to each other. Further, a direction which is orthogonal to each of the optical axis direction (z direction) and the first direction (y direction) is called as a second direction (x direction).

The cylindrical lens **612** is a lens which contracts the light flux in the first direction (y direction), that is, has a refracting power in the first direction (y direction). A focal distance in the first direction (y direction) by the cylindrical lens **612** is f_1. Further, the cylindrical lens (anamorphic lens) **613** is a lens which contracts the light flux in the second direction (x direction), that is, has a refracting power only in the second direction (x direction). A focal distance in the second direction (x direction) by the cylindrical lens **613** is set such that a converging position coincides with the cylindrical lens **612**. In other words, the focal distance of the cylindrical lens **613** is shorter than the focal distance f_1 of the cylindrical lens **612**. Accordingly, the input light coming to the parallel lights by the micro lens **611** is converged approximately on a primary converging surface Sf by the cylindrical lenses **612** and **613**.

A front focal point position of the lens **614** coincides with the converging position of the input light by the cylindrical lenses **612** and **613**. In other words, the front focal point position of the lens **614** is positioned on the primary converging surface Sf. Further, the optical axis of the optical system including the cylindrical lenses **612** and **613** and the lens **614** is arranged so as to pass through the input and output port **610***c* along the z axis direction. Further, the dispersing portion **615** is arranged at a position where a distance between the primary converging surface Sf and the lens **614**, and a distance between the lens **614** and the dispersing (diffracting) surface of the dispersing portion **615** are both equally a focal distance f_3 of the lens **614**. The dispersing portion **615** is constructed, for example, by a diffraction grating in which parallel gratings in the first direction (y direction) are formed on the dispersing surface. As the dispersing portion **615**, a resolving power of the light per wavelength is desirably higher and a dispersing angle is desirably larger.

As shown in FIG. **15**B, the input light passing through the lens **614** enters as the approximately parallel lights into the dispersing portion **615**, and is dispersed at different angles per wavelength in the x direction on the dispersing surface of the dispersing portion **615**. In other words, the dispersing portion **615** separates the input light into the lights per wavelength included in the input light. For simplicity reason, the light path in the z direction from the input portion **610** to the deflector **617** is linearly shown in FIG. **15**A.

Further, the lens **616** and the deflector **617** are arranged such that each of a distance from the dispersing surface of the dispersing portion **615** to the lens **616**, and a distance from the lens **616** to the deflecting element surface (mirror surface) of the deflecting element **618** of the deflector **617** comes to a focal distance f_4 of the lens **616**. Accordingly, as shown in FIG. **15**B, the light per wavelength dispersed by the dispersing portion **615** comes to a light ray having parallel main light rays in each of the wavelengths by the lens **616**, and enters approximately vertically into the deflecting elements **618***a* to **618***e* corresponding to the wavelengths. Further, as shown in FIG. **15**A, the input light passing through the converging point on the primary converging surface Sf is dispersed by the dispersing portion **615**, and thereafter converges at a height position where the optical axis of the lens **616** and the deflecting element surface of the deflecting element **618** intersect within a yz plane.

The deflector **617** is constructed, for example, by a MEMS mirror array, and the deflecting element **618** is constructed by a micro mirror forming the MEMS mirror array. The deflecting elements **618** are arranged in parallel in the x direction in correspondence to the separated wavelength. The deflecting element **618** can independently controls the mirrors so as to change the incline. Particularly, the deflecting element reflects the incident light per wavelength in a different height direction from the incident direction by changing the incline in the yz plane in FIG. **15**A. As shown in FIG. **15**B, the light per wavelength enters vertically into the deflecting elements **618***a* to **618***e* as seen from the y axis direction, and is reflected vertically.

The light per wavelength reflected by each of the deflecting elements **618**_a_ to **618**_e_ is diffracted by the dispersing portion **615** through the lens **616**, and is output to any of the output ports **610**_b_ to **610**_e_ of the input and output portion **610** through the light path in the opposite direction to the input light.

In FIG. **15**A, a distance position of the input and output port **610**_a_ from the optical axis of the optical system constructed by the cylindrical lenses **612** and **613** and the lens **614** is Y_1. The input light from the input and output port **610**_a_ is converged onto the primary converging surface Sf as shown by a solid line in FIG. **15**A, thereafter comes to parallel lights having a distance Y_2 from the optical axis by the lens **614**, is dispersed per wavelength by the dispersing portion **615**, and converges into the deflecting elements **618**_a_ to **618**_e_ per wavelength.

Here, in the case that at least one wavelength light in the lights input to the deflecting elements **618**_a_ to **618**_e_ is output from the input and output port **610**_d_, a particular wavelength light is reflected in a predetermined direction as shown by a broken line in FIG. **15**A by controlling the deflecting direction of the corresponding deflecting element **618**. The particular wavelength light reflected by the deflecting element **618** passes through the lens **616**, and is output from the input and output port **610**_d_ via the dispersing portion **615**, the lens **614**, the cylindrical lenses **613** and **612**, and the corresponding micro lens of the micro lens array **611**. In the case that a plurality of output wavelength lights exist in the same input and output port **610**_d_, a plurality of wavelength lights are combined by the dispersing portion **615**.

Next, a description will be in detail given of the eighth embodiment with reference to the accompanying drawings.

FIG. **16** is a top elevational view showing an outline structure of the wavelength selecting switch **601** according to the eighth embodiment of the present invention. The wavelength selecting switch **601** employs the Littman-Metcalf type dispersing portion **615** which is constructed by a dispersing element **622** constituted by transmission type diffraction gratings and a mirror (a reflection element) **623**, in the wavelength selecting switch **601** described in FIGS. **15**A and **15**B. Further, in the wavelength selecting switch **601**, the converting lens **621** doubles as the lens **614** and the lens **616** in FIGS. **15**A and **15**B by folding back the light path of the light dispersed per wavelength by the dispersing portion **615**. A description will be in detail given below.

The wavelength selecting switch **601** according to the eighth embodiment is structured such as to include the input and output portion **610**, the micro lens array **611**, the cylindrical lenses **612** and **613**, the converging lens **621**, the transmission type dispersing element **622**, the mirror (the reflection element) **623** and the deflector **617**.

The input and output portion **610**, the micro lens array **611**, and the cylindrical lenses **612** and **613** are the same optical elements as described in the basic structure mentioned above. The converging lens **621** is arranged between the cylindrical lens **613** and the dispersing element **622**, in such a manner that the distance in the z direction between the converging lens **621** and the converging point by the cylindrical lenses **612** and **613**. and the distance from the center of the dispersing element **622** become equal to the focal distance of the converging lens **621**. Here, the optical axis of the optical system constructed by the micro lens of the micro lens array **611** and the cylindrical lenses **612** and **613** and the optical axis of the converging lens **621** are arranged so as to be shifted in the second direction (x direction). The height positions in the first direction (y direction) of the optical axes are the same. Further, the deflector **617** is arranged at a position where the converging point by the cylindrical lenses **612** and **613** is approximately equal to the position in the z direction in a state in which the deflecting element **618** is directed to the converging lens **621** side, and is arranged so as to be shifted in the second direction (x direction) to the side where the optical axis of the converging lens **621** passes. In other words, the distance between the converging lens **621** and the deflecting element of the deflector **617** is also the focal distance of the converging lens **621**.

The dispersing element **622** and the mirror **623** form the dispersing portion **615** having a so-called Littman-Metcalf type configuration. In other words, the m-order transmission diffraction light by the dispersing element **622** is reflected by the mirror **623**, and is again exposed to the m-order diffraction by the dispersing element **622** so as to transmit. As mentioned above, by the transmission through the dispersing element twice and the diffraction, the dispersing angle can be enlarged. Here, m is a desired order which is previously defined at a design time, and is the other integers than 0, for example, 1.

According to the structure mentioned above, the input light input from the input and output port **610**_a_ of the output portion **610** comes to the parallel lights by the micro lens array **611**, is converged by the cylindrical lenses **612** and **613**, thereafter comes to the parallel beams by the converging lens **621**, and enters into the dispersing portion **615**. The input light entering into the dispersing portion **615** is exposed twice the m-order diffraction corresponding to the desired order by transmitting twice the dispersing element **622** so as to be dispersed into the light per wavelength. The dispersed lights per wavelength are respectively converged on the different deflecting elements **618** of the deflector **617** by the converging lens **621**. The lights per wavelength are reflected at different angles per wavelength by the deflecting element **618**, are folded on the light path until being reflected by the deflecting element **618**, and are output from the any input and output ports **610**_b_ to **610**_e_ of the input portion **610**. Hereinafter, the light passing through the light path is called as a normal light.

On the other hand, in a diffraction grating surface (a second surface **622**_b_ mentioned later) of the dispersing element **622** of the dispersing portion **615**, a m-order reflection diffraction light is generated in addition to the m-order desired transmission diffraction light corresponding to the normal light. Hereinafter, the diffraction light having the different order from the normal light, and the light which is reflected by the surface to be transmitted the normal light or which transmits the surface to be reflected are called as a noise light. In the present embodiment, the m-order reflection diffraction light is designed such that the m-order reflection diffraction light does not enter into the deflecting element **618** of the deflector **617**. A description will be given below of details thereof.

FIG. **17** is a top elevational view describing the light paths of the normal light and the noise light in the dispersing portion in FIG. **16**. In this drawing, L_i denotes a wavelength multiplexed input light, L_{s1}, L_{s2} and L_{s3} denote normal lights which are separated per respective wavelengths λ_{s1}, λ_{s2} and λ_{s3}, and L_{n1} and L_{n2}, denote a first noise light and a second noise light. The input light L_i enters into the first surface **622**_a_ of the dispersing element **622** from an oblique direction at a predetermined angle.

FIG. **18** is a view showing a structure of the dispersing element **622** in FIG. **16**. In this drawing, the input light L_i, and the predetermined wavelength (for example, λ_{s2}) light in the lights diffracted per wavelength are illustrated. The dispersing element **622** is formed by bonding a transmission type diffraction grating **622**_d_ and a wedge-shaped prism **622**_c_ by an adhesive bonding layer **622**_e_. The transmission type diffraction grating **622**_d_ is structured such that one surface of the parallel flat surfaces is set to the diffraction grating surface **622***b*, and the other surface is set to a flat optical surface (hereinafter, refer to as an optical plane) with no diffraction. The wedge-shaped prism **622***c* is constructed by the same material as the transmission type diffraction grating **622***d*, has the optical planes which face to each other, and are not parallel in the optical planes. Further, the adhesive bonding layer **622***e* employs a pressure sensitive adhesive having approximately the same refraction factor as the transmission type diffraction grating **622***d* and the wedge-shaped prism **622***c*.

The diffraction element **622** is not constructed only by the parallel planar transmission type diffraction grating **622***d* which is parallel in its diffraction grating surface to the optical plane, because of the following reasons. In the case that the dispersing element **622** is constructed only by the transmission type diffraction grating **622***d*, the input light, for example, passing through the optical plane is regularly reflected by the diffraction grating surface and the optical plane in the dispersing element **622** respectively, and there is generated a stray light path which receives the m-order diffraction by the diffraction grating surface so as to pass through the diffracting grating surface and emit. In this case, there is generated a problem that the stray light and the normal light form the parallel lights so as to cause interference. In the normal case, the stray light can be suppressed by applying an AR coat onto the optical plane, however, in an optical communication field to which the present invention is applied, since a severe signal quality is requested, a countermeasure by the AR coat is insufficient. Accordingly, the problem of interference is solved by tilting the first surface **622***a* serving as the optical plane of the dispersing element **622** and the second surface **622***b* serving as the diffraction grating surface. In this case, since the diffraction grating having a high quality which is used for the optical communication is manufactured by using a semiconductor process, it is hard to construct the substrate itself as a wedge shape. Therefore, the diffraction grating is manufactured by laminating the transmission type diffraction grating and the wedge-shaped prism.

Further, in the case that a quartz is used as a material of the transmission type diffraction grating **622***d* and the wedge-shaped prism **622***c*, an angle (a wedge angle) between two optical plane of the wedge-shaped prism **622***c* is preferably set to about 4.4 degrees. In this angle, a change of a diffraction angle due to the change of the refraction factor of the dispersing element caused by the temperature change, and a change of the diffraction angle due to the change of a grating constant of the diffraction grating caused by a line expansion are cancelled with each other. Accordingly, even in the case that the temperature of the dispersing element **622** changes within the wavelength selecting switch **601**, the emitting angle of the transmission diffraction light does not change. Therefore, the wavelength selecting switch **601** can be used in a wide temperature range without carrying out any position adjustment of the deflector **617**.

FIGS. **19**A and **19**B are views describing the bonding between the transmission type diffraction grating **622***d* of the diffraction grating and the wedge-shaped prism **622***c*, and a change (FIG. **19**A) of a refraction factor n_e in relation to a position in a thickness direction of the dispersing element **622** is shown by coordinating with a structure (FIG. **19**B) of the dispersing element **622** in the thickness direction. A micro structure which is smaller than the wavelength of the input light is formed in a surface in the adhesive bonding layer **622***e* side of the transmission type diffraction grating **622***d*, as shown in FIG. **19**B. As mentioned above, by setting the micro structure, an effective refraction factor change of the adhesive bonding layer **622***e* and the transmission type diffraction grating **622***d* becomes gentle as shown in FIG. **19**A, and it is possible to make demand to a refraction factor alignment between the transmission type diffraction grating **622***d* and the pressure sensitive adhesive **622***e* small. As a result, it is possible to suppress a reflection by an interface between the transmission type diffraction grating and the adhesive bonding layer **622***e*. The micro structure is not an essential structure in the present embodiment, and the micro process may not be formed as long as the refraction factor alignment between the transmission type diffraction grating **622***d* and the pressure sensitive adhesive **622***e* has a sufficient precision.

The transmission type diffraction grating **622***d* and the wedge-shaped prism **622***c* may be directly bonded on the basis of an optical contact by precisely grinding the bonded surfaces of the transmission type diffraction grating **622***d* and the wedge-shaped prism **622***c* flat, in place of the adhesive bonding layer **622***e*.

In FIG. **17**, the light path of the normal light is as follows. In other words, the input light L_i entering into the dispersing element **622** is refracted by the first surface **622***a* serving as the optical plane of the dispersing element, is exposed to the m-order diffraction by the second surface **622***b* serving as the diffraction grating surface so as to transmit, is reflected by the mirror surface **623***a* of the mirror **623**, is again exposed to the m-order diffraction by the diffraction grating surface of the dispersing element **622** so as to transmit, and is emitted as the normal lights L_{s1}, L_{s2} and L_{s3} per wavelength. In FIG. **17**, L_{s1}, L_{s2} and L_{s3} respectively correspond to the different wavelengths λ_1, λ_2 and λ_3 included in the input light, and λ_1 is the shortest wavelength and λ_3 is the longest wavelength. In FIG. **17**, in the light path of the normal light before being emitted from the dispersing element **622**, only the light having the wavelength $\lambda 2$ is shown. Here, m is the other integers than 0, for example, 1.

On the other hand, in the optical system, the first and second noise lights L_{n1} and L_{n2} are generated by the following light path. The first noise light L_{n1} is the light which the input section L_i light is exposed to the m-order diffraction so as to be reflected at a time of entering into the second surface **622***b* of the dispersing element **622** first time. Further, the second noise light L_{n2} is the light which the transmission diffraction light passing through the second surface **522***b* is reflected by the reflection mirror **623**, is thereafter exposed to the m-order diffraction so as to be reflected at a time of entering into the diffraction grating surface second time, is further reflected by the mirror **623**, and is exposed to the m-order diffraction so as to pass through the second surface **622***b* of the dispersing element **622**. The first noise light L_{n1} and the second noise light L_{n2} are designed so that the emitting angle range from the dispersing portion **615** does not lap over the normal light which is diffracted at the desired order m by the diffraction grating **622**. If the angle ranges of the lights emitted from the dispersing portion **615** do not overcome, the converging position of the noise light in the deflector does not lap over the converging position of the normal light.

FIG. **20** is a view describing an angle relationship between the dispersing element **622** and the mirror **623** constructing the dispersing portion **615**, and the normal light passing through the dispersing portion. This drawing shows a light path of the normal light L_s about a predetermined wavelength light in the input light L_i In the drawing, α is an angle between the first surface **622***a* serving as the optical plane of the wedge-shaped dispersing element **622**, and the second surface **622***b* serving as the diffraction grating surface, and is 4.42 degrees as mentioned above. β is an angle between the mirror **623***a* of the mirror **623** and the second surface **622***b* of the dispersing element **622**. Further, θ_1 and θ_2 are respectively an incident angle and an emitting angle in relation to the first surface **622***a* of the dispersing element **622** of the input light L_i. θ_3 and θ_4 are respectively an incident angle in relation to the second surface **622***b* of the dispersing element **622** of the normal light passing through the first surface, and an emitting angle of the normal light exposed to the m-order diffraction. θ_5 and θ_6 are respectively an incident angle and a reflecting angle in relation to the reflection surface **623***a* of the normal light. θ_7 and θ_8 are respectively an incident angle in relation to the second surface **622***b* of the dispersing element **622** and an emitting angle of the m-order diffraction transmission diffracted light, in the normal light reflected by the reflection surface **623***a*. θ_9 and θ_{10} are respectively an incident angle and an emitting angle in relation to the first surface **622***a* of the normal light passing through the second surface of the dispersing element **622** by being exposed to the diffraction. With regard to α and β, a direction of an arrow in the drawing is set to positive, and with regard to the other angles, the direction of the light ray from the vertical line of each of the surface is set to positive when the direction is clockwise.

The angles α, β, and θ_1 to θ_{10} satisfy the following relational expression.

$$n(\lambda)\sin\theta_2(\lambda) = \sin\theta_1(\lambda) \tag{1}$$

$$\theta_3(\lambda) = \theta_2(\lambda) - \alpha \tag{2}$$

$$n(\lambda)\sin\theta_3(\lambda) - \sin\theta_4(\lambda) = \frac{m_1\lambda}{d} \tag{3}$$

$$\theta_5(\lambda) = \theta_4(\lambda) + \beta \tag{4}$$

$$\theta_6(\lambda) = -\theta_5(\lambda) \tag{5}$$

$$\theta_7(\lambda) = \theta_6(\lambda) - \beta \tag{6}$$

$$n(\lambda)\sin\theta_8(\lambda) - \sin\theta_7(\lambda) = \frac{m_2\lambda}{d} \tag{7}$$

$$\theta_9(\lambda) = \theta_8(\lambda) + \alpha \tag{8}$$

$$\sin\theta_{10}(\lambda) = n(\lambda)\sin\theta_9(\lambda) \tag{9}$$

Here, λ is a wavelength of the normal light, $n(\lambda)$ is a refraction factor of the member of the dispersing element, d is a grating constant of the diffraction grating, and m_1 and m_2 are order of diffraction, for example, 1 in the present embodiment. If α, β and $\theta_1(\lambda)$ are given, θ_2 to θ_{10} are sequentially defined by the expressions (1) to (9).

FIG. **21** is a view describing an angular relationship between the noise light and the normal light which are generated in the dispersing portion in FIG. **16**. Emitting angles $\theta_{10}(\lambda_1)$, $\theta_{10}(\lambda_2)$ and $\theta_{10}(\lambda_3)$ from the first surface **622***a* of the dispersing element **622** of the normal lights L_{s1}, L_{s2} and L_{s3} are angles which are defined on the basis of the expressions (1) to (9) in the case that the angles α, and β and the angle θ_1 are given. Further, as the first noise light L_{n1} and the second noise light L_{n2}, the light path in the case of the wavelength λ_2 is shown representatively. In FIG. **21**, $\phi_1(\lambda_2)$ is a diffraction angle of reflection in the second surface **622***b* of the first noise light L_{n1} which the normal light is reflected by being exposed to the m-order diffraction by the second surface **622***b* of the dispersing element **622**, and $\phi_2(\lambda_2)$ is an emitting angle of the first noise light L_{n1} reflection diffracted by the second surface **622***b* at a time of passing through the first surface **622***a* of the dispersing element **622**. Further, $\phi_3(\lambda_2)$ is a diffraction angle of reflection in the second surface **622***b* of the second noise light L_{n2} which the normal light transmission diffracted by the second surface **622***b* of the dispersing element **622** is reflected by the mirror **623***a* and is thereafter reflected by being exposed to the m-order diffraction at a time of entering into the second surface **622***b* second time. Further, $\phi_4(\lambda_2)$ and $\phi_5(\lambda_2)$ are respectively an incident angle and a reflection angle in relation to the second surface **622***b*, at a time when the second noise light L_{n2} reflection diffracted by the second surface **622***b* is again reflected by the mirror surface **623***a* and passes through the second surface **622***b* of the dispersing element **622** by being exposed to the m-order diffraction. Further, $\phi_6(\lambda_2)$ is an emitting angle at a time when the second noise light L_{n2} transmission diffracted by the second surface **622***b* of the dispersing element **622** passes through the first surface **622***a* of the dispersing element **622**.

$\phi_1(\lambda)$ to $\phi_6(\lambda)$ satisfy the following relational expression by using α and β and θ_1 to θ_{10} obtained by the expressions (1) to (9).

$$\sin\theta_3(\lambda) + \sin\phi_1(\lambda) = \frac{m_3\lambda}{dn(\lambda)} \tag{10}$$

$$\sin\phi_2(\lambda) = n(\lambda)\sin(\phi_1(\lambda) + \alpha) \tag{11}$$

$$\sin\phi_3(\lambda) + \sin\theta_7(\lambda) = \frac{m_4\lambda}{d} \tag{12}$$

$$\phi_4(\lambda) = -\phi_3(\lambda) - 2\beta \tag{13}$$

$$n(\lambda)\sin\phi_5(\lambda) - \sin\phi_4(\lambda) = \frac{m_5\lambda}{d} \tag{14}$$

$$\sin\phi_6(\lambda) = n(\lambda)\sin(\phi_5(\lambda) + \alpha) \tag{15}$$

Here, m_3, m_4 and m_5 indicate the order of the diffraction, for example, 1 in the present embodiment. According to the expression (11), the emitting angle $\phi_2(\lambda)$ from the dispersing portion **615** of the first noise light L_{n1} can be obtained. Further, according to the expression (15), the emitting angle $\phi_6(\lambda)$ from the dispersing portion **615** of the second noise light L_{n2} can be obtained.

In the deflector **617**, in order to prevent the first noise light L_{n1} and the second noise light L_{n2} from entering into the deflecting element **618** into which the normal light L_2 enters, it is necessary for the emitting angle range of the normal light about all the wavelengths λ of the wavelength multiplexed input light, and the emitting angle range of the first noise light L_{n1} and the second noise light L_{n2} about all the wavelength to be prevented from overlapping. FIG. **22**A is a view showing a relationship of the emitting angles (θ, Φ) in relation to the wavelength (λ) of the normal light and the noise light in the case that an interference of the normal light and the noise light is generated. Further, FIG. **22**B is a view showing a relationship of the emitting angles (θ_{10}, ϕ_2 and ϕ_6) in relation to the wavelength (λ) of the normal light and the noise light in the eighth embodiment. An overlapping portion (δ) exists between the emitting angle of the normal light and the emitting angle of the noise light in the wavelength range between the maximum value λ_1 and the minimum value λ_s of the wavelength λ of the input light as shown in FIG. **22**A, a noise light undesirably enters into the deflecting element **618** of the deflector **617**. It is desirable that the emitting angles of the normal light and the noise light are completely separated as shown in FIG. **22**B.

In other words, in the case that the maximum value of the wavelength λ of the input light is set to λ_1, the minimum value is set to λ_s, and the emitting angles from the dispersing portion **615** of the normal light L_s diffracted by the desired order, the first noise light L_{n1} and the second noise light L_{n2} about the respective wavelengths λ of the input light are respectively set to $\theta_o(\lambda)(=\theta_{10})$, $\phi_{o1}(\lambda)(=\phi_2)$ and $\phi_{o2}(\lambda)(=\phi_6)$, these factors may satisfy the following expressions (16) and (17).

$$\max_{\lambda_s\le\lambda\le\lambda_1}\phi_{o1}(\lambda) < \min_{\lambda_s\le\lambda\le\lambda_1}\theta_o(\lambda) \text{ or } \max_{\lambda_s\le\lambda\le\lambda_1}\theta_o(\lambda) < \min_{\lambda_s\le\lambda\le\lambda_1}\phi_{o1}(\lambda) \tag{16}$$

$$\max_{\lambda_s\le\lambda\le\lambda_1}\phi_{o2}(\lambda) < \min_{\lambda_s\le\lambda\le\lambda_1}\theta_o(\lambda) \text{ or } \max_{\lambda_s\le\lambda\le\lambda_1}\theta_o(\lambda) < \min_{\lambda_s\le\lambda\le\lambda_1}\phi_{o2}(\lambda) \tag{17}$$

wherein

$$\max_{\lambda_s\le\lambda\le\lambda_1} f(\lambda),\ \min_{\lambda_s\le\lambda\le\lambda_1} f(\lambda)$$

are maximum and minimum value of $f(\lambda)$ in the range of $\lambda_s \le \lambda \le \lambda_1$.

If the incident angle θ_1 of the input light, the angle α (=4.42 degrees), the refraction factor $n(\lambda)$ of the medium of the β dispersing element **622**, and the parameter of the grating period d of the diffraction grating are given, $\theta_o(\lambda)(=\theta_{10})$, $\phi_{o1}(\lambda)(=\phi_2)$ and $\phi_{o2}(\lambda)(=\phi_6)$ can be calculated on the basis of the expressions (1) to (15). By appropriately setting the parameters, the expressions (16) and (17) can be satisfied in relation to the maximum value λ_1 and the minimum value λ_s of the desired wavelength of the wavelength selecting switch.

Further, as shown in FIG. **16**, a light absorbing body **619** is provided as a noise light inhibiting portion at a position where a noise light L_n generated in the dispersing portion **615** enters into an outer side where the reflection element **618** is not arranged on the deflector **617**. The light absorbing body **619** is structured such as to inhibit the noise light from being emitted to the output port on the basis of the reflection in the wavelength selecting switch **601**. Specifically, the light absorbing body can be formed by using a material including carbon such as a carbon sheet, or a material obtained by mixing a coloring matter having an infrared ray absorbing characteristic to a resin. Here, a member having a reflection surface for reflecting the noise light in a direction that the noise light does not enter into the output ports **610***b* to **610***e* may be provided as the noise inhibiting portion in place of the light absorbing body **619**. Further, an incident interface of the light absorbing body **619** may be processed as the reflection surface.

Embodiment 1

Table 1 shows design examples 1 to 4 of the dispersing portion **615** of the wavelength selecting switch on the basis of the present invention. In the embodiment, a frequency of the signal light is in a range between 191.3 and 196.3 THz.

TABLE 1

Parameter	Design Example 1	Design Example 2	Design Example 3	Design Example 4
Medium	Quart	Quart	Quart	Quart
1/d	950	950	950	950
θ_1	59.2	47.79	64.35	52.72
α	2	2	4.42	4.42
β	43.31	53.05	43.22	53.07
θ_{10}	49.28-55.99	40.94-46.53	54.71-62.35	44.90-50.72
ϕ_2	42.64-45.61	52.76-56.42	47.44-50.61	57.45-61.50
ϕ_6	56.70-73.21	34.52-39.94	63.47-90	38.36-43.90

In all the design examples 1 to 4 of Table 1, the angle range does not overlap between the emitting angle (θ_{10}) of the normal light and the emitting angle (ϕ_2, ϕ_6) of the noise light. Particularly, in the design example 2 and the design example 4, since the incident angle θ_1 of the input light does not lap over the angle range of the noise light, these design examples are advantageous in a point that the cross talk is not generated by the return of the noise light having the particular wavelength into the input port. Further, in the design example 3 and the design example 4, since the angle (wedge angle) α formed by the first surface **622***a* and the second surface **622***b* of the dispersing element **622** is set to 4.42 degrees, the refraction factor change of the medium and the change of the grating constant due to the linear expansion act so as to cancel the influences applied to the emitting angle with each other in the case that the temperature change is generated within the casing of the wavelength selecting switch **601**. Therefore, the design 4 is more preferable among the design examples 1 to 4.

As mentioned above, according to the present embodiment, since the normal light L_s which is diffracted at the desired order by the diffraction grating, and the noise light L_n which is diffracted at the different order or the different mode from the desired order, are structured such that the emitting angle ranges from the dispersing portion **615** do not overlap, the normal light and the noise light do not enter in an overlapping manner on the deflecting element **618** of the deflector **617**. Therefore, a ripple is not generated by the interference between the normal light and the noise light having the same wavelength, on the basis of the incident of the noise light into any output port **610***b* to **610***e*. Accordingly, it is possible to prevent a transmission band characteristic from being deteriorated due to the undesired diffraction on the diffraction grating surface of the wavelength selecting switch.

Further, since each of the optical members is designed in such a manner as to efficiently pass through the desired path on the interface, a light intensity as the noise light becomes smaller if a frequency of passing through a different path from the desired path is increased. The noise light is efficiently output from the output port in the reciprocating optical system as mentioned above, in the case that the path from the deflector **617** toward the output port becomes in reverse to the path from the input port to the deflector **617**. Therefore, in the case of setting a frequency of passing in the different path from the desired path to n, and setting a rate of the different path from the desired path uniformly to S for simplifying, from the input port to the deflector **617**, the light intensity of the noise light is in proportion to 2n power of S. Since the noise light path shown by the present embodiment is guided to the deflector **617** with only one different path from the desired path, in each of the interfaces within the dispersing portion, attenuation of the light intensity is smaller than the other paths, and the noise light path is particularly important.

Further, a diffraction efficiency of the diffraction grating is generally designed so as to be the best in the vicinity of a Littrow angle. Further, in the case that a certain incident angle is a Littrow condition for the m-order diffraction of the transmission, this case satisfies by itself the Littrow condition of the m-order diffraction of the reflection. Accordingly, the signal light and the noise light in the present embodiment are necessarily emitted approximately in the same direction from the dispersing portion by designing the optical system of the wavelength selecting switch attaching importance only to the efficiency, and deterioration of the transmission band characteristic is generated. Therefore, in order to inhibit the transmission band characteristic from being deteriorated, it is effective to positively use the structure in the present embodiment.

Further, since the light absorbing member absorbing the noise light is provided as the noise light inhibiting portion for inhibiting the noise light from emitting to the output port in the portion where the deflecting element **618** is not arranged in the deflecting portion **617**, the noise light reflected by a part of the deflecting portion approximately existing on the same plane as the deflecting element **618** is prevented from entering as the stray light into the output port.

Further, it is possible to prevent the cross talk from being generated by the return of the noise light having the particular wavelength to the input port, by setting the incident angle of the input light to the dispersing portion so as not to lap over the angle range of the noise light, as shown by the design example 4 of the embodiment.

Ninth Embodiment

FIG. **23** is a top elevational view showing an outline structure of a wavelength selecting switch according to a ninth embodiment of the present invention. In the present embodiment, the dispersing portion **615** in the basic structure mentioned above is constructed by combining a dispersing element **632** and two mirrors **633** and **634**. A lens **631** and a lens **635** which are arranged in a front stage and a rear stage of the dispersing portion **615** are constructed by a spherical convex lens, and respectively correspond to the lenses **614** and **616** in the basic structure.

In FIG. **23**, among the wavelength multiplexed input lights emitting from the input and output portion **610**, only the light path of the normal light having the particular wavelength is shown by a solid line. Further, the noise light L_n which the normal light passing through the optical axis is regularly reflected (that is, reflected in O order) by the dispersing element **632** is shown by a broken line. The broken line only shows an example of the light path of the noise light, however, the wavelength selecting switch **601** according to the present embodiment is designed in such a manner that the emitting angle range from the dispersing portion **615** of the noise light which is regularly reflected by the dispersing element **632** does not lap over the emitting angle range from the dispersing portion **615** of the normal light which is diffracted in the desired order by the dispersing portion **615**.

FIG. **24** is a top elevational view describing the light path of the normal light and the noise light in the dispersing portion **615** in FIG. **23**. In this drawing, L_i denotes the wavelength multiplexed input light, L_{s1}, L_{s2} and L_{s3} respectively denote the normal lights which are separated per wavelengths λ_{s1}, λ_{s2} and λ_{s3}, and L_n denotes the noise light. The input light L_i enters into the dispersing element **632** at a predetermined angle. The dispersing element **632** is a diffraction grating in which a first surface **632***a* in an incident side of the input light L_i is a diffraction grating surface, and a second surface **632***b* opposed to the first surface is an optical plane. The first surface **632***a* and the second surface **632***b* are not parallel therebetween.

The wavelength multiplexed input light L_i which is input from the input port **610***a* of the input and output portion **610** is exposed to the m-order diffraction by the first surface **632***a* so as to transmit and be dispersed into the lights L_{s1}, L_{s2}, and L_{s3} per wavelengths, and is reflected on the second surface **632***b* so as to transmit. The lights L_{s1}, L_{s2}, and L_{s3} per wavelengths passing through the dispersing element **632** are reflected sequentially by the first mirror (the first reflection element) **633** and the second mirror (the second reflection element) **634**. The lights per wavelengths reflected by the second mirror **634** enter into the second surface **632***b* of the dispersing element **632** so as to be reflected, and is further exposed to the -m-order diffraction by the first surface **632***a* so as to transmit. As mentioned above, in the present embodiment, the light exposed to the desired m-order and -m-order diffractions by the diffraction grating surface **632***a* of the dispersing element is called as the normal light.

On the other hand, when the wavelength multiplexed input light L_i enters into the first surface **632***a* of the dispersing element **632** first time, the regularly reflected light comes to the noise light L_n which is emitted from the dispersing portion **615** at a close angle to the normal light.

FIG. **25** is a view describing an angle relationship between the noise light and the normal light which are generated in the dispersing portion in FIG. **23**. The drawing shows a light path of the normal light L_{s2} about a predetermined wavelength in the input light L_i. In FIG. **25**, α is an angle between the first surface **632***a* and the second surface **632***b* of the wedge-shaped dispersing element **622**, and is set to 4.42 degrees. β is an angle between the mirror surface of the mirror **633** and the second surface **632***b* of the dispersing element **632**, and γ is an angle between the mirror surface of the mirror **634** and ht second surface **632***b* of the dispersing element **632**. Further, θ_{11} and θ_{12} respectively denote an incident angle of the input light L_i in relation to the first surface **632***a* of the dispersing element **632** and an emitting angle of the m-order transmission diffraction light of the input light L_i. θ_{13} and θ_{14} respectively denote an incident angle and an emitting angle of the normal light passing through the first surface **632***a* in relation to the second surface **632***b* of the dispersing element **632**. θ_{15} and θ_{16} respectively denote an incident angle at which the normal lights sequentially reflected by the mirrors **633** and **634** after emitting from the dispersing element **632** enter into the second surface **632***b* of the dispersing element **632**, and an emitting angle of the normal light which passes through the second surface **632***b*. θ_{17} and θ_{18} respectively denote an incident angle of the normal light which enters into the first surface **632***a* after passing through the second surface **632***b* of the dispersing element **632**, and an emitting angle of the transmission diffraction light which is exposed to the -m-order diffraction by the first surface **632***a*. Further, ϕ_7 denotes a reflection angle of the noise light L_n obtained by the regular reflection of the input light L_i by the first surface of the dispersing element **632**.

The angles α, β, γ, θ_{11} to θ_{18} and ϕ_7 mentioned above satisfy the following relational expression.

$$n(\lambda)\sin\theta_{12}(\lambda) - \sin\theta_{11}(\lambda) = \frac{m_6\lambda}{d} \tag{18}$$

$$\theta_{13}(\lambda) = \theta_{12}(\lambda) - \alpha \tag{19}$$

$$\sin\theta_{14}(\lambda) = n(\lambda)\sin\theta_{13}(\lambda) \tag{20}$$

$$\theta_{15}(\lambda) = 2(\beta + y - 90) + \theta_{14}(\lambda) \tag{21}$$

$$n(\lambda)\sin\theta_{16}(\lambda) - \sin\theta_{15}(\lambda) \tag{22}$$

$$\theta_{17}(\lambda) = \theta_{16}(\lambda) + \alpha \tag{23}$$

$$n(\lambda)\sin\theta_{17}(\lambda) - \sin\theta_{18}(\lambda) = \frac{m_7\lambda}{d} \tag{24}$$

$$\sin\theta_{11}(\lambda) + \sin\theta_7(\lambda) = \frac{m_8\lambda}{d} \tag{25}$$

Here, λ denotes a wavelength of the normal light, $n(\lambda)$ denotes a reflection factor of the member of the dispersing element, d denotes a grating constant of the diffraction grating, and m_6, m_7 and m_8 denote orders of diffraction, for example, −1, 1 and 0 respectively in the present embodiment. If the angles α (=4.42 degrees), β and γ, and the incident angle θ_{11} of the input light L_i are given, θ_{12} to θ_{18} and ϕ_7 are sequentially defined by the expressions (18) to (25).

In order to prevent the noise light L_n from entering into the deflecting element **618** into which the normal light L_s enters, in the deflector **617**, it is necessary for the emitting angle ranges of the normal light L_s about the wavelengths λ of all the wavelength multiplexed input lights to be prevented from lapping over the emitting angel ranges of the noise lights L_n about all the wavelengths λ. In other words, in the case of setting the maximum value and the minimum value of the wavelength λ of the input light L_i to λ_1 and λ_s, and setting the emitting angles from the dispersing portion **61** of the normal light L_s and the noise light L_n which are diffracted by the desired order, about the wavelengths λ of the input light to $\theta_o(\lambda)$ (=$\theta_{18}(\lambda)$) and $\phi_o(\lambda)$ (=$\phi_7(\lambda)$), respectively, the factors may satisfy the following expression (26).

$$\max_{\lambda_s\le\lambda\le\lambda_1}\phi_o(\lambda) < \min_{\lambda_s\le\lambda\le\lambda_1}\theta_o(\lambda) \text{ or } \max_{\lambda_s\le\lambda\le\lambda_1}\theta_o(\lambda) < \min_{\lambda_s\le\lambda\le\lambda_1}\phi_o(\lambda) \qquad (26)$$

In relation to the parameters of the incident angle θ_{11} of the input light L_i, the angles α (=4.42 degrees), β and γ, the refraction factor $n(\lambda)$ of the medium of the dispersing element **632**, and the grating constant d of the diffraction grating, $\theta_o(\lambda)(=\theta_{18})$ and $\phi_o(\lambda)(=\phi_7)$ can be calculated on the basis of the expressions (18) to (24). By appropriately setting these parameters, the expression (26) can be satisfied in relation to the maximum value λ_1 and the minimum value λ_s of the desired wavelength of the wavelength selecting switch.

Further, as shown in FIG. **23**, reflecting members **620***a* and **620***b* serving as a noise light inhibiting portion are provided at a position where the noise light L_n generated by the dispersing portion **615** enters into an outer side where the deflecting element **618** is not arranged on the deflector **617**. The reflecting members **620***a* and **620***b* have reflecting surfaces which reflect the noise light in a direction that the noise light does not enter into the output ports **610***b* to **610***e*, and inhibit the noise light L_n from being emitted to the output port. The other structures and operations are the same as the eighth embodiment, and the same reference numerals are attached to the same constructing elements, and a description thereof will be omitted.

As described above, according to the present embodiment, even in the case that the dispersing portion **615** constructed by using the diffraction grating and two mirrors **633** and **634** is used as shown in FIGS. **23** and **25**, the normal light L_s diffracted at the desired order by the diffraction grating surface of the dispersing element **632** is prevented from lapping over the noise light L_n diffracted at the different order or according to the different mode from the desired order, in the emitting angle range from the dispersing portion **615**, in the same manner as the eighth embodiment. Therefore, the normal light and the noise light do not enter in an overlapping manner on the deflecting element **618** of the deflector **617**. Accordingly, the noise light does not enter into any of the output ports **610***b* to **610***e*, and the ripple due to interference between the normal light and the noise light is not generated. Therefore, it is possible to prevent the transmission band characteristic caused by the undesired diffraction on the diffraction grating of the wavelength selecting switch from being deteriorated.

Further, since the portion where the deflecting element **618** is not arranged in the deflecting portion **617** is provided with the reflecting members **620***a* and **620***b* having the reflecting surfaces which reflect the noise light in the direction that the noise light does not enter into the output ports **610***b* to **610***e*, as the noise light inhibiting portion for inhibiting the noise light from emitting to the output port, it is possible to inhibit the noise light reflected by a part of the deflecting portion existing on approximately the same plane as the deflecting element **618** from entering into the output port as the stray light.

It is apparent for those skilled in the art that the present invention can be variously changed and replaced within the scope and the range of the present invention. Accordingly, the present invention should not be understood to be limited by the embodiments mentioned above, but can be variously modified and changed without deflecting from the scope of the claims.

For example, the optical systems shown in the first and fourth embodiments, the optical system shown in the second embodiment, and the optical system shown in the third embodiment respectively have the different structures, however, each of the optical systems is only one example, and does not restrict each of the structures of the light path compensating portions mentioned above. In other words, the structures of the light path compensating portions shown in the first and fourth embodiments can be applied to the optical system shown in the second or third embodiment. On the contrary, the structures of the light path compensating portions shown in the second and third embodiments can be applied to the optical systems shown in the first, fourth and fifth embodiments.

More specifically, in the arrangement of each of the members within the casing **118** in the first embodiment, the compensating plate **116** may be rotated by using the magnetic body **330** such as the third embodiment, in place of the driving of the compensating plate **116** by the actuator **117**. Further, in the second embodiment, the reflection element **212***b* may be rotated by using the magnetic body **330** such as the third embodiment, in place of the driving of the rotation of the reflection element **212***b* by the actuator **217**. Further, the optical fiber array may be constructed by a light guide. Further, the first, second and third converging elements **113***a*, **113***b* and **113***c* are not limited to the lenses, but can employ a converging mirror, a diffraction type converting element and the like as long as the converting elements achieve the converging action. Further, the reflection mirror for folding the light path may be arranged or not be arranged as occasion demands. Further, as long as the light flux input from the input port is constructed by the parallel light fluxes, the light fluxes may not be necessarily made in parallel by a collimate element such as the micro lens array.

In the seventh embodiment, the deflecting portion **550** may be supported by the support portion **571** in such a manner as to directly deflect the light which is wavelength dispersed by the dispersing portion **530** by the deflecting portion **550** by omitting the reflection prism **581**. Further, the opening portion **571***b* formed in the support portion **571** may be formed as various hole shapes, or may be formed as a notched shape which is open in the top face plate **560***b* side or the bottom face plate **560***f* side of the casing **560**. Further, the opening portion **571***b* may be formed by a transparent member such as glass in a whole of the support portion **571**, as long as the opening portion transmits the input light and the output light.

Further, since the dispersing portion **530** and the converging lens **540** is comparatively larger in the project area of the part in comparison with the other optical parts, and the parts layout is restricted, at least the dispersing portion **530** and the converging lens **540** may be supported by the optical base plate **570** attached to the back face plate **560***e*, and the other optical parts may be supported by the other optical base plate, for example, attached to the bottom face plate **560f**.

Further, the converging lens **540** may employ a converging mirror, or a diffraction type converging element as long as the converging action can be achieved. Further, in each of the embodiments, the micro lens array **520** may not be necessarily arranged. Further, the dispersing portion is not limited to the transmission type disperse element or the Littman-Metcalf configuration, but can employ a reflection type diffraction grating, Grism, a super prism and the like.

Further, in the eighth and ninth embodiments, the structure of the dispersing portion **615** is not limited to the exemplified structure, but can be applied to various dispersing portion structures.

Further, the input and output portion **610** is not limited to the portion having one input port, but can be structured such that a plurality of input ports are provided. Further, in place of the cylindrical lenses **612** and **613**, one spherical convex lens may be arranged. Further, the ninth embodiment may be structured such that the cylindrical lenses **612** and **613** and the lens **631** are not provided, and the input light collimated by the micro lens of the micro lens array **611** is directly entered into the dispersing portion **615**.

Further, in the eighth and ninth embodiment, the preferable angle between two non-parallel surfaces of the dispersing element **622** is set to 4.42 degrees, however, the effect of the present invention can be obtained at the other angles than this angle.

REFERENCE NUMERALS

100, **200**, **300**, **400** wavelength selecting switch
101, **201**, **301** optical unit for wavelength selecting switch
109, **209**, **309**, **409** optical fiber array
110, **210**, **310**, **410** input and output port
110*a* input port
110*b* output port
111, **211**, **311**, **411** lens array
112, **412** dispersing portion
113*a*, **213***a*, **313***a* first converging element
113*b*, **213***b*, **313***b* second converging element
113*c*, **213***c*, **313***c* third converging element
114 mirror portion
115, **215**, **315** deflecting portion
116, **316**, **416** compensating plate
117, **217** actuator
118, **218**, **318** casing
119, **219**, **319** window
120, **220**, **320** deflecting portion casing
121, **221** adjusting portion
122, **322** support body
123, **323** rotary shaft
124 elastic body
125 stopper
212*a* discharging element
212*b* reflection element
212*c* reflection element moving member
312 Grism
314*a* first mirror portion
314*b* second mirror portion
326 temperature compensating prism
327, **427** retaining portion
328, **428** magnet
330 elastic body
441 pressure sensitive adhesive sealing portion
442 ultraviolet light curable pressure sensitive adhesive
442*a* first liquid
442*b* second liquid
443 transparent window
444 magnet for pressure sensitive adhesive
445 magnetic bead
510*a* input port
510*b*-**510***e* output port
530 dispersing portion
531 dispersing element
533 folding mirror
540 converging lens
541 primary converging lens
550 deflecting portion
551*a*-**551***e* deflecting element
560 casing
560*b* top face plate
560*c*, **560***d* side face plate
560*e* back face plate
560*f* bottom face plate
561 support table
562 screw
563 sealant
565 screw
570 optical base plate
570*a*, **570***b*, **570***c*, **570***d*, **570***e* support surface
571 support portion
571*a* support surface
571*b* opening portion
580 folding mirror
581 reflection prism
601 wavelength selecting switch
610 input and output portion
610*a*-**610***e* input and output port
611 micro lens array
612 cylindrical lens
613 cylindrical lens
614 lens
615 dispersing portion
616 lens
617 deflector
618 deflecting element
619 light absorbing body
620*a*, **620***b* reflecting member
621 converging lens
622 dispersing element
622*d* transmission type diffraction grating
622*c* wedge-shaped prism
622*b* adhesive bonding layer
622*a* first surface
622*e* second surface
623 mirror
631 lens
632 dispersing element
633 first mirror
634 second mirror
635 lens
633*a* reflecting surface
Y1, **Y2** distance from optical axis
L_i input light
L_s, L_{s1}, L_{s2}, L_{s3} normal light
L_n, L_{n1}, L_{n2} noise light
Sf primary converging surface
Sm deflecting element surface

The invention claimed is:

1. A wavelength selecting switch comprising:

at least one input port for emitting an input light;

a lens array for converting light from the at least one input port into parallel lights;

a dispersing portion which disperses the input light into a plurality of wavelengths;

a converging element which receives the plurality of wavelengths dispersed in a wavelength dispersion direction, and which converges each wavelength dispersed by the dispersing portion;

a deflecting portion which independently deflects each wavelength converged by the converging element;

a plurality of output ports which outputs the light deflected by the deflecting portion as one or more output lights;

an optical bench including a support surface, which supports at least the dispersing portion and the converging element; and

a casing which accommodates and retains the optical bench, and which includes first and second orthogonal faceplates;

wherein the optical bench is attached to the first faceplate, whereby the support surface is orthogonal to a surface of the second faceplate, which has the greatest project area of the casing.

2. The wavelength selecting switch according to claim **1**, wherein the at least one input port and the output ports are arranged linearly,

wherein the deflecting portion is supported by a support portion which protrudes out of the support surface of the optical bench among the input port, the output port and the converging element, and

wherein a light transmission portion transmitting the input light and the output light between the input and output ports and the converging element is formed in the support portion.

3. The wavelength selecting switch according to claim **2**, further comprising a primary converging lens forming a primary converging point, the primary converging lens being arranged among the input port, the output port and the converging element,

wherein the support portion is arranged whereby the light transmitting portion is positioned at the primary converging point or in the vicinity thereof, and

wherein the dispersing portion, the converging element and the deflecting portion are arranged whereby the input light from the input port is dispersed by the dispersing portion through the primary converging lens and the converging element, and the dispersed light is deflected by the deflecting portion through the converging element, and is output as the output light from the output port through the dispersing portion and the converging element.

4. The wavelength selecting switch according to claim **1**, wherein the support surface is orthogonal to the wavelength dispersion direction.

5. The wavelength selecting switch according to claim **1**, wherein the converging element comprises an optical lens including an optical axis; and wherein the optical axis of the optical lens is parallel to the support surface.

6. The wavelength selecting switch according to claim **1**, wherein the deflecting portion extends from the support surface, and comprises a plurality of deflecting elements arranged linearly in an arranging direction, which is parallel to the second faceplate.

7. The wavelength selecting switch according to claim **6**, further comprising a a reflection prism for reflecting the wavelengths from the converging element to the deflecting elements orthogonal to the first faceplate; wherein the reflection prism extends vertically from the support surface.

8. The wavelength selecting switch according to claim **1**, wherein the input and output ports are mounted on the support surface, and are arranged linearly in a direction parallel to the support surface.

9. The wavelength selecting switch according to claim **1**, wherein the support surface comprises:

a first support surface supporting the converging element;

a second support surface supporting the dispersing portion; and

a third support surface at an incline to the first support surface supporting each input port and each output port.

10. The wavelength selecting switch according to claim **9**, further comprising a folding mirror for reflecting the wavelengths from the converging element to the deflecting elements orthogonal to the first faceplate.

* * * * *